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ACC gene

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ACC gene

The present invention relates to a gene useful in a process to increase the microbial production of carotenoids.

The carotenoid astaxanthin is distributed in a wide variety of organisms such as animals, algae and microorganisms. It has a strong antioxidation property against reactive oxygen species. Astaxanthin is used as a coloring reagent, especially in the industry of farmed fish, such as salmon, because astaxanthin imparts distinctive orange-red coloration to the animals and contributes to consumer appeal in the marketplace.

One of the first steps in the carotenogenic pathway of, e.g. *Phaffia rhodozyma*, is the condensation of two molecules of acetyl-CoA. Acetyl-CoA is also the substrate for acetyl-CoA carboxylase, one of the enzymes involved in fatty acid biosynthesis.

In one aspect, the present invention provides a novel DNA fragment comprising a gene encoding the enzyme acetyl-CoA carboxylase.

More particularly, the present invention provides a DNA containing regulatory regions, such as promoter and terminator, as well as the open reading frame of acetyl-CoA carboxylase gene.

The present invention provides a DNA fragment encoding acetyl-CoA carboxylase in *P. rhodozyma*. The said DNA means a cDNA which contains only open reading frame flanked between the short fragments in its 5'- and 3'- untranslated region, and a genomic DNA which also contains its regulatory sequences such as its promoter and terminator which are necessary for the expression of the acetyl-CoA carboxylase gene in *P. rhodozyma*.

Accordingly, the present invention relates to a polynucleotide comprising a nucleic acid molecule selected from the group consisting of:

(a) nucleic acid molecules encoding at least the mature form of the polypeptide depicted in SEQ ID NO:3;

(b) nucleic acid molecules comprising the coding sequence as depicted in SEQ ID NO:2;

(c) nucleic acid molecules whose nucleotide sequence is degenerate as a result of the genetic code to a nucleotide sequence of (a) or (b);

(d) nucleic acid molecules encoding a polypeptide derived from the polypeptide encoded by a polynucleotide of (a) to (c) by way of substitution, deletion and/or addition of one or several amino acids of the amino acid sequence of the polypeptide encoded by a polynucleotide of (a) to (c);

(e) nucleic acid molecules encoding a polypeptide derived from the polypeptide whose sequence has an identity of 56.3 % or more to the amino acid sequence of the polypeptide encoded by a nucleic acid molecule of (a) or (b);

(f) nucleic acid molecules comprising a fragment or a epitope-bearing portion of a polypeptide encoded by a nucleic acid molecule of any one of (a) to (e) and having acetyl-CoA carboxylase activity;

(g) nucleic acid molecules comprising a polynucleotide having a sequence of a nucleic acid molecule amplified from *Phaffia* or *Xanthophylomyces* nucleic acid library using the primers depicted in SEQ ID NO:4, 5, and 6;

(h) nucleic acid molecules encoding a polypeptide having acetyl-CoA carboxylase activity, wherein said polypeptide is a fragment of a polypeptide encoded by any one of (a) to (g);

(i) nucleic acid molecules comprising at least 15 nucleotides of a polynucleotide of any one of (a) to (d);

(j) nucleic acid molecules encoding a polypeptide having acetyl-CoA carboxylase activity, wherein said polypeptide is recognized by antibodies that have been raised against a polypeptide encoded by a nucleic acid molecule of any one of (a) to (h);

(k) nucleic acid molecules obtainable by screening an appropriate library under stringent conditions with a probe having the sequence of the nucleic acid molecule of any one of (a) to (j), and encoding a polypeptide having an acetyl-CoA carboxylase activity;

(l) nucleic acid molecules whose complementary strand hybridizes under stringent conditions with a nucleic acid molecule of any one of (a) to (k), and encoding a polypeptide having acetyl-CoA carboxylase activity.

The terms "gene(s)", "polynucleotide", "nucleic acid sequence", "nucleotide sequence", "DNA sequence" or "nucleic acid molecule(s)" as used herein refers to a polymeric form of

nucleotides of any length, either ribonucleotides or deoxyribonucleotides. This term refers only to the primary structure of the molecule.

Thus, this term includes double- and single- stranded DNA, and RNA. It also includes known types of modifications, for example, methylation, "caps" substitution of one or more of the naturally occurring nucleotides with an analog. Preferably, the DNA sequence of the invention comprises a coding sequence encoding the above-defined polypeptide.

A "coding sequence" is a nucleotide sequence which is transcribed into mRNA and/or translated into a polypeptide when placed under the control of appropriate regulatory sequences. The boundaries of the coding sequence are determined by a translation start codon at the 5'-terminus and a translation stop codon at the 3'-terminus. A coding sequence can include, but is not limited to mRNA, cDNA, recombinant nucleotide sequences or genomic DNA, while introns may be present as well under certain circumstances. SEQ ID:1 depicts the genomic DNA in which the intron sequence is inserted in the coding sequence for acetyl-CoA carboxylase gene from *P. rhodozyma*.

In general, the gene consists of several parts which have different functions from each other. In eukaryotes, genes which encode a corresponding protein, are transcribed to premature messenger RNA (pre-mRNA) differing from the genes for ribosomal RNA (rRNA), small nuclear RNA (snRNA) and transfer RNA (tRNA). Although RNA polymerase II (PolII) plays a central role in this transcription event, PolII can not solely start transcription without *cis* element covering an upstream region containing a promoter and an upstream activation sequence (UAS), and a *trans*-acting protein factor. At first, a transcription initiation complex which consists of several basic protein components recognize the promoter sequence in the 5'-adjacent region of the gene to be expressed. In this event, some additional participants are required in the case of the gene which is expressed under some specific regulation, such as a heat shock response, or adaptation to a nutrition starvation, and so on. In such a case, a UAS is required to exist in the 5'-untranslated upstream region around the promoter sequence, and some positive or negative regulator proteins recognize and bind to the UAS. The strength of the binding of transcription initiation complex to the promoter sequence is affected by such a binding of the *trans*-acting factor around the promoter, and this enables the regulation of transcription activity.

After the activation of a transcription initiation complex by the phosphorylation, a transcription initiation complex initiates transcription from the transcription start site. Some parts of the transcription initiation complex are detached as an elongation complex from the promoter region to the 3' direction of the gene (this step is called as a promoter

clearance event) and the elongation complex continues the transcription until it reaches to a termination sequence that is located in the 3'-adjacent downstream region of the gene. Pre-mRNA thus generated is modified in nucleus by the addition of cap structure at the cap site which almost corresponds to the transcription start site, and by the addition of polyA stretches at the polyA signal which is located at the 3'-adjacent downstream region. Next, intron structures are removed from the coding region and exon parts are combined to yield an open reading frame whose sequence corresponds to the primary amino acid sequence of a corresponding protein. This modification in which a mature mRNA is generated is necessary for a stable gene expression. cDNA in general terms corresponds to the DNA sequence which is reverse-transcribed from this mature mRNA sequence. It can be synthesized by the reverse transcriptase derived from viral species by using a mature mRNA as a template, experimentally.

To express a gene which was derived from eukaryote, a procedure in which cDNA is cloned into an expression vector for *E. coli* is often used. This results from the fact that a specificity of intron structure varies among the organisms and an inability to recognize the intron sequence from other species. In fact, prokaryote has no intron structure in its own genetic background. Even in yeast, the genetic background is different between *Ascomycetes* to which *Saccharomyces cerevisiae* belongs and *Basidiomycetes* to which *P. rhodozyma* belongs, e.g. the intron structure of the actin gene from *P. rhodozyma* cannot be recognized nor spliced by the ascomycetous yeast, *S. cerevisiae*.

Intron structures of some kinds of the genes appear to be involved in the regulation of the expression of their genes. It might be important to use a genomic fragment which has its introns in a case of self-cloning of the gene of a interest whose intron structure involves such a regulation of its own gene expression.

To apply a genetic engineering method for a strain improvement study, it is necessary to study its genetic mechanism in the event such as transcription and translation. It is important to determine a genetic sequence such as its UAS, promoter, intron structure and terminator to study the genetic mechanism.

According to this invention, the gene encoding the acetyl-CoA carboxylase (*ACC*) gene from *P. rhodozyma* including its 5'- and 3'-adjacent regions as well as its intron structure was determined.

The invention further encompasses polynucleotides that differ from one of the nucleotide sequences shown in SEQ ID NO:2 (and portions thereof) due to degeneracy of the genetic

code and also encode an acetyl-CoA carboxylase as that encoded by the nucleotide sequences shown in SEQ ID NO:2. Further the polynucleotide of the invention has a nucleotide sequence encoding a protein having an amino acid sequence shown in SEQ ID NO:3. In a still further embodiment, the polynucleotide of the invention encodes a full length *P. rhodozyma* protein which is substantially homologous to an amino acid sequence of SEQ ID NO:3.

In addition, it will be appreciated by those skilled in the art that DNA sequence polymorphism that lead to changes in the amino acid sequences may exist within a population (e.g., the *P. rhodozyma* population). Such genetic polymorphism in the acetyl-CoA carboxylase gene may exist among individuals within a population due to natural variation.

As used herein, the terms "gene" and "recombinant gene" refer to nucleic acid molecules comprising an open reading frame encoding an acetyl-CoA carboxylase, preferably an acetyl-CoA carboxylase from *P. rhodozyma*.

Such natural variations can typically result in 1-5 % variance in the nucleotide sequence of the acetyl-CoA carboxylase gene. Any and all such nucleotide variations and resulting amino acid polymorphism in acetyl-CoA carboxylase that are the result of natural variation and that do not alter the functional activity of acetyl-CoA carboxylase are intended to be within the scope of the invention.

Polynucleotides corresponding to natural variants and non-*P. rhodozyma* homologues of the acetyl-CoA carboxylase cDNA of the invention can be isolated based on their homology to *P. rhodozyma* acetyl-CoA carboxylase polynucleotides disclosed herein using the polynucleotide of the invention, or a portion thereof, as a hybridization probe according to standard hybridization techniques under stringent hybridization conditions. Accordingly, in another embodiment, a polynucleotide of the invention is at least 15 nucleotides in length. Preferably it hybridizes under stringent conditions to the nucleic acid molecule comprising a nucleotide sequence of the polynucleotide of the present invention, e.g. SEQ ID NO:2. In other embodiments, the nucleic acid is at least 20, 30, 50, 100, 250 or more nucleotides in length. The term "hybridizes under stringent conditions" is defined above and is intended to describe conditions for hybridization and washing under which nucleotide sequences at least 60% identical to each other typically remain hybridized to each other. Preferably, the conditions are such that sequences at least about 65% or 70%, more preferably at least about 75% or 80%, and even more preferably at least about 85%, 90% or 95% or more identical to each other typically remain hybridized to each other. Preferably, polynucleotide of the invention that hybridizes under stringent

conditions to a sequence of SEQ ID NO:2 corresponds to a naturally occurring nucleic acid molecule.

In the present invention, the polynucleotide sequence includes SEQ ID NO:2 and fragments thereof having polynucleotide sequences which hybridize to SEQ ID NO:2 under stringent conditions which are sufficient to identify specific binding to SEQ ID NO:2. For example, any combination of the following hybridization and wash conditions may be used to achieve the required specific binding:

High Stringent Hybridization: 6X SSC, 0.5% SDS, 100 µg/ml denatured salmon sperm DNA, 50% formamide, incubate overnight with gentle rocking at 42°C.

High Stringent Wash: 1 wash in 2X SSC, 0.5% SDS at room temperature for 15 minutes, followed by another wash in 0.1X SSC, 0.5% SDS at room temperature for 15 minutes.

Low Stringent Hybridization: 6X SSC, 0.5% SDS, 100 µg /ml denatured salmon sperm DNA, 50% formamide, incubate overnight with gentle rocking at 37°C.

Low Stringent Wash: 1 wash in 0.1X SSC, 0.5% SDS at room temperature for 15 minutes.

Moderately stringent conditions may be obtained by varying the temperature at which the hybridization reaction occurs and/or the wash conditions as set forth above. In the present invention, it is preferred to use high stringent hybridization and wash conditions to define the antisense activity against acetyl-CoA carboxylase gene from *P. rhodozyma*.

The term "homology" means that the respective nucleic acid molecules or encoded proteins are functionally and/or structurally equivalent. The nucleic acid molecules that are homologous to the nucleic acid molecules described above and that are derivatives of said nucleic acid molecules are, for example, variations of said nucleic acid molecules which represent modifications having the same biological function, in particular encoding proteins with the same or substantially the same biological function. They may be naturally occuring variations, such as sequences from other plant varieties or species, or mutations. These mutations may occur naturally or may be obtained by mutagenesis techniques. The allelic variations may be naturally occurring allelic variants as well as synthetically produced or genetically engineered variants. Structural equivalents can, for example, be identified by testing the binding of said polypeptides to antibodies. Structural equivalents have similar immunological characteristics, e.g. comprise similar epitopes.

As used herein, a "naturally-occurring" nucleic acid molecule refers to an RNA or DNA molecule having a nucleotide sequence that occurs in nature (e.g., encodes a natural protein). Preferably, the polynucleotide encodes a natural *P. rhodozyma* acetyl-CoA carboxylase.

acid or nucleic acid "homology" is equivalent to amino acid or nucleic acid "identity"). The percent homology between the two sequences is a function of the number of identical positions shared by the sequences (i.e., % homology = numbers of identical positions/total numbers of positions x 100). The homology can be determined by computer programs as Blast 2.0 [Altschul, Nuc. Acid. Res., 25:3389-3402 (1997)]. In this invention, GENETYX-SV/RC software (Software Development Co., Ltd., Tokyo, Japan) is used by using its default algorithm as such homology analysis software. This software uses the Lipman-Pearson method for its analytic algorithm.

A nucleic acid molecule encoding an acetyl-CoA carboxylase homologous to a protein with an amino acid sequence of SEQ ID NO:3 can be created by introducing one or more nucleotide substitutions, additions or deletions into a nucleotide sequence of the polynucleotide of the present invention, in particular of SEQ ID NO:2 such that one or more amino acid substitutions, additions or deletions are introduced into the encoded protein. Mutations can be introduced into the sequences of, e.g., SEQ ID NO:2 by standard techniques, such as site-directed mutagenesis and PCR-mediated mutagenesis. Preferably, conservative amino acid substitutions are made at one or more predicted non-essential amino acid residues. A "conservative amino acid substitution" is one in which the amino acid residue is replaced with an amino acid residue having a similar side chain. Families of amino acid residues having similar side chains have been defined in the art. These families include amino acids with basic side chains (e.g., lysine, arginine, histidine), acidic side chains (e.g., aspartic acid, glutamic acid), uncharged polar side chains (e.g., glycine, asparagine, glutamine, serine, threonine, tyrosine, cysteine), nonpolar side chains (e.g., alanine, valine, leucine, isoleucine, proline, phenylalanine, methionine, tryptophan), beta-branched side chains (e.g., threonine, valine, isoleucine) and aromatic side chains (e.g., tyrosine, phenylalanine, tryptophan, histidine). Thus, a predicted nonessential amino acid residue in an acetyl-CoA carboxylase is preferably replaced with another amino acid residue from the same family. Alternatively, in another embodiment, mutations can be introduced randomly along all or part of an acetyl-CoA carboxylase coding sequence, such as by saturation mutagenesis, and the resultant mutants can be screened for an acetyl-CoA carboxylase activity described herein to identify mutants that retain acetyl-CoA carboxylase activity. Following mutagenesis of one of the sequences of SEQ ID NO:2, the encoded protein can be expressed recombinantly and the activity of the protein can be determined using, for example, assays described herein.

A polynucleotide of the present invention, e.g., a nucleic acid molecule having a nucleotide sequence of SEQ ID NO:2, or a portion thereof, can be isolated using standard molecular

Preferably, the polypeptide of the invention comprises one of the nucleotide sequences shown in SEQ ID NO:2. The sequence of SEQ ID NO:2 corresponds to the *P. rhodozyma* acetyl-CoA carboxylase cDNAs of the invention.

Further, the polynucleotide of the invention comprises a nucleic acid molecule which is a complement of one of the nucleotide sequences of above mentioned polynucleotides or a portion thereof. A nucleic acid molecule which is complementary to one of the nucleotide sequences shown in SEQ ID NO:2 is one which is sufficiently complementary to one of the nucleotide sequences shown in SEQ ID NO:2 such that it can hybridize to one of the nucleotide sequences shown in SEQ ID NO:2, thereby forming a stable duplex.

The polynucleotide of the invention comprises a nucleotide sequence which is at least about 60%, preferably at least about 65-70%, more preferably at least about 70-80%, 80-90%, or 90-95%, and even more preferably at least about 95%, 96%, 97%, 98%, 99% or more homologous to a nucleotide sequence shown in SEQ ID NO:2, or a portion thereof. The polynucleotide of the invention comprises a nucleotide sequence which hybridizes, e.g., hybridizes under stringent conditions as defined herein, to one of the nucleotide sequences shown in SEQ ID NO:2, or a portion thereof.

Moreover, the polynucleotide of the invention can comprise only a portion of the coding region of one of the sequences in SEQ ID NO:2, for example a fragment which can be used as a probe or primer or a fragment encoding a biologically active portion of an acetyl-CoA carboxylase. The nucleotide sequences determined from the cloning of the acetyl-CoA carboxylase gene from *P. rhodozyma* allows for the generation of probes and primers designed for use in identifying and/or cloning acetyl-CoA carboxylase homologues in other cell types and organisms. The probe/primer typically comprises a substantially purified oligonucleotide. The oligonucleotide typically comprises a region of nucleotide sequence that hybridizes under stringent conditions to at least about 12, 15 preferably about 20 or 25, more preferably about 40, 50 or 75 consecutive nucleotides of a sense strand of one of the sequences set forth, e.g., in SEQ ID NO: No:2; an anti-sense sequence of one of the sequences, e.g., set forth in SEQ ID NO:2, or naturally occurring mutants thereof. Primers based on a nucleotide of invention can be used in PCR reactions to clone acetyl-CoA carboxylase homologues. Probes based on the acetyl-CoA carboxylase nucleotide sequences can be used to detect transcripts or genomic sequences encoding the same or homologous proteins. The probe can further comprise a label group attached thereto, e.g. the label group can be a radioisotope, a fluorescent compound, an enzyme, or an enzyme co-factor. Such probes can be used as a part of a genomic marker test kit for identifying cells which express an acetyl-CoA carboxylase, such as by measuring a level of

an acetyl-CoA carboxylase-encoding nucleic acid molecule in a sample of cells, e.g., detecting acetyl-CoA carboxylase mRNA levels or determining whether a genomic acetyl-CoA carboxylase gene has been mutated or deleted.

The polynucleotide of the invention encodes a polypeptide or portion thereof which includes an amino acid sequence which is sufficiently homologous to an amino acid sequence of SEQ ID NO:3 such that the protein or portion thereof maintains an acetyl-CoA carboxylase activity, in particular an acetyl-CoA carboxylase activity as described in the examples in microorganisms or plants. As used herein, the language "sufficiently homologous" refers to proteins or portions thereof which have amino acid sequences which include a minimum number of identical or equivalent (e.g., an amino acid residue which has a similar side chain as an amino acid residue in one of the sequences of the polypeptide of the present invention amino acid residues to an amino acid sequence of SEQ ID NO:3 such that the protein or portion thereof has an acetyl-CoA carboxylase activity. Examples of an acetyl-CoA carboxylase activity are also described herein.

The protein is at least about 60-65%, preferably at least about 66-70%, and more preferably at least about 70- 80%, 80-90%, 90-95%, and most preferably at least about 96%, 97%, 98%, 99% or more homologous to an entire amino acid sequence of SEQ ID NO:3.

Portions of proteins encoded by the acetyl-CoA carboxylase polynucleotide of the invention are preferably biologically active portions of one of the acetyl-CoA carboxylase.

As mentioned herein, the term "biologically active portion of acetyl-CoA carboxylase" is intended to include a portion, e.g., a domain/motif, that has acetyl-CoA carboxylase activity or has an immunological activity such that it is binds to an antibody binding specifically to acetyl-CoA carboxylase. To determine whether an acetyl-CoA carboxylase or a biologically active portion thereof can participate in the metabolism an assay of enzymatic activity may be performed. Such assay methods are well known to those skilled in the art, as detailed in the Examples. Additional nucleic acid fragments encoding biologically active portions of an acetyl-CoA carboxylase can be prepared by isolating a portion of one of the sequences in SEQ ID NO:2, expressing the encoded portion of the acetyl-CoA carboxylase or peptide (e.g., by recombinant expression *in vitro*) and assessing the activity of the encoded portion of the acetyl-CoA carboxylase or peptide.

At first, a partial gene fragment was cloned containing a portion of the ACC gene by using the degenerate PCR method. Said degenerate PCR is a method to clone a gene of interest which has high homology of amino acid sequence to the known enzyme from other species

which has the same or similar function. Degenerate primer, which is used as a primer in degenerate PCR, was designed by a reverse translation of the amino acid sequence to corresponding nucleotides ("degenerated"). In such a degenerate primer, a mixed primer which consists any of A, C, G or T, or a primer containing inosine at an ambiguity code is generally used. In this invention, such mixed primers were used for degenerate primers to clone above gene.

An entire gene containing its coding region with its intron as well as its regulation region such as a promoter or a terminator can be cloned from a chromosome by screening of a genomic library which is constructed in phage vector or plasmid vector in appropriate host, by using a partial DNA fragment obtained by degenerate PCR as described above as a probe after it was labeled. Generally, *E. coli* as a host strain and *E. coli* vector, a phage vector such as λ phage vector, or a plasmid vector such as pUC vector is often used in the construction of a library and a following genetic manipulation such as a sequencing, a restriction digestion, a ligation and the like. In this invention, an *EcoRI* genomic library of *P. rhodozyma* was constructed in the derivatives of λ vector, λZAPII. An insert size, what length of insert must be cloned, was determined by the Southern blot hybridization for the gene before construction of a library. In this invention, a DNA used for a probe was labeled with digoxigenin (DIG), a steroid hapten instead of conventional ^{32}P label, following the protocol which was prepared by the supplier (Boehringer-Mannheim, Mannheim, Germany). A genomic library constructed from the chromosome of *P. rhodozyma* was screened by using a DIG-labeled DNA fragment which had a portion of a gene of interest as a probe. Hybridized plaques were picked up and used for further study. When λZAPII (insert size was below 9kb) was used in the construction of the genomic library, in vivo excision protocol was conveniently used for the succeeding step of the cloning into the plasmid vector by using a derivative of single stranded M13 phage, Ex assist phage (Stratagene, La Jolla, USA). A plasmid DNA thus obtained was examined for sequencing.

In this invention, we used the automated fluorescent DNA sequencer, ALFred system (Pharmacia, Uppsala, Sweden) using an autocycle sequencing protocol in which the Taq DNA polymerase is employed in most cases of sequencing.

After the determination of the genomic sequence, a sequence of a coding region was used for a cloning of cDNA of corresponding gene. The PCR method was also exploited to clone cDNA fragment. The PCR primers whose sequences were identical to the sequence at the 5'- and 3'- end of the open reading frame (ORF) were synthesized with an addition of an appropriate restriction site, and PCR was performed by using those PCR primers. In

The present invention further relates to a vector in which the polynucleotide of the present invention is operatively linked to expression control sequences allowing expression in prokaryotic or eukaryotic host cells. The nature of such control sequences differs depending upon the host organism. In prokaryotes, control sequences generally include promoter, ribosomal binding site, and terminators. In eukaryotes, generally control sequences include promoters, terminators and, in some instances, enhancers, transactivators; or transcription factors.

The term "control sequence" is intended to include, at a minimum, components the presence of which are necessary for expression, and may also include additional advantageous components.

The term "operably linked" refers to a juxtaposition wherein the components so described are in a relationship permitting them to function in their intended manner. A control sequence "operably linked" to a coding sequence is ligated in such a way that expression of the coding sequence is achieved under conditions compatible with the control sequences. In case the control sequence is a promoter, it is obvious for a skilled person that double-stranded nucleic acid is used.

Regulatory sequences include those which direct constitutive expression of a nucleotide sequence in many types of host cell and those which direct expression of the nucleotide sequence only in certain host cells or under certain conditions. It will be appreciated by those skilled in the art that the design of the expression vector can depend on such factors as the choice of the host cell to be transformed, the level of expression of protein desired, etc. The expression vectors of the invention can be introduced into host cells to thereby produce proteins or peptides, including fusion proteins or peptides, encoded by polynucleotides as described herein.

The recombinant expression vectors of the invention can be designed for expression of acetyl-CoA carboxylase in prokaryotic or eukaryotic cells. For example, genes encoding the polynucleotide of the invention can be expressed in bacterial cells such as *E. coli*, insect cells (using baculovirus expression vectors), yeast and other fungal cells, algae, ciliates of the types: *Holotrichia, Peritrichia, Spirotrichia, Suctoria, Tetrahymena, Paramecium, Colpidium, Glaucoma, Platyophrya, Potomacus, Pseudocohnilembus, Euplotes, Engelmaniella,* and *Stylonychia*, especially *Stylonychia lemnae* with vectors following, a transformation method as described in WO9801572 and multicellular plant cells. Alternatively, the recombinant expression vector can be transcribed and translated *in vitro*, for example using T7 promoter regulatory sequences and T7 polymerase.

utilized in the bacterium chosen for expression, such as *E. coli*. Such alteration of nucleic acid sequences of the invention can be carried out by standard DNA synthesis techniques.

Further, the acetyl-CoA carboxylase vector can be a yeast expression vector. Examples of vectors for expression in yeast *S. cerevisiae* include pYepSec1, pMPa, pJRY88, and pYE52 (Invitrogen, San Diego, USA). Vectors and methods for the construction of vectors appropriate for use in other fungi, such as the filamentous fungi, are known to the skilled artisan.

Alternatively, the polynucleotide of the invention can be introduced in insect cells using baculovirus expression vectors. Baculovirus vectors available for expression of proteins in cultured insect cells (e.g., Sf 9 cells) include the pAc series and the pVL series.

Alternatively, the polynucleotide of the invention is introduced in mammalian cells using a mammalian expression vector. Examples of mammalian expression vectors include pCDM8 and pMT2PC. When used in mammalian cells, the expression vector's control functions are often provided by viral regulatory elements. For example, commonly used promoters are derived from polyoma, Adenovirus 2, cytomegalovirus and Simian Virus 40.

The recombinant mammalian expression vector can be capable of directing expression of the nucleic acid preferentially in a particular cell type (e.g., tissue-specific regulatory elements are used to express the nucleic acid). Tissue- specific regulatory elements are known in the art. Non-limiting examples of suitable tissue-specific promoters include the albumin promoter (liver- specific), lymphoid-specific promoters, in particular promoters of T cell receptors and immunoglobulins, neuron-specific promoters (e.g., the neurofilament promoter), pancreas-specific promoters, and mammary gland-specific promoters (e.g., milk whey promoter; US 4,873, 316 and EP 264,166). Developmentally-regulated promoters are also encompassed, for example the murine hox promoters and the fetoprotein promoter.

Thus expressed ACC gene can be verified for its activity, e.g., by an enzyme assay method. Some experimental protocols are described in the literature. The following is the one of the methods which is used for the determination of acetyl-CoA carboxylase activity: Assays are performed by measuring the loss in acetyl-CoA and/or the production of malonyl-CoA at 5 min intervals for 20 min, using reverse phase HPLC. The rate of conversion of acetyl-CoA to malonyl-CoA is found to be linear for 20 min, and velocities are calculated by linear regression analysis of the malonyl-CoA concentration with respect to time. The

gene fragment would form a complex with a mature mRNA fragment of the objective gene *in vivo* and inhibit an efficient translation from mRNA, as a consequence.

An "antisense" nucleic acid molecule comprises a nucleotide sequence which is complementary to a "sense" nucleic acid molecule encoding a protein, e.g., complementary to the coding strand of a double-stranded cDNA molecule or complementary to a mRNA sequence. Accordingly, an antisense nucleic acid molecule can hydrogen bond to a sense nucleic acid molecule. The antisense nucleic acid molecule can be complementary to an entire acetyl-CoA carboxylase-coding strand, or to only a portion thereof. Accordingly, an antisense nucleic acid molecule can be antisense to a "coding region" of the coding strand of a nucleotide sequence encoding an acetyl-CoA carboxylase. The term "coding region" refers to the region of the nucleotide sequence comprising codons which are translated into amino acid residues. Further, the antisense nucleic acid molecule is antisense to a "noncoding region" of the coding strand of a nucleotide sequence encoding acetyl-CoA carboxylase. The term "noncoding region" refers to 5' and 3' sequences which flank the coding region that are not translated into a polypeptide (i.e., also referred to as 5' and 3' untranslated regions).

Given the coding strand sequences encoding acetyl-CoA carboxylase disclosed herein, antisense nucleic acid molecules of the invention can be designed according to the rules of Watson and Crick base pairing. The antisense nucleic acid molecule can be complementary to the entire coding region of acetyl-CoA carboxylase mRNA, but can also be an oligonucleotide which is antisense to only a portion of the coding or noncoding region of acetyl-CoA carboxylase mRNA. For example, the antisense oligonucleotide can be complementary to the region surrounding the translation start site of acetyl-CoA carboxylase mRNA. An antisense oligonucleotide can be, for example, about 5, 10, 15, 20, 25, 30, 35, 40, 45 or 50 nucleotides in length. An antisense nucleic acid molecule of the invention can be constructed using chemical synthesis and enzymatic ligation reactions using procedures known in the art. For example, an antisense nucleic acid molecule (e.g., an antisense oligonucleotide) can be chemically synthesized using naturally occurring nucleotides or variously modified nucleotides designed to increase the biological stability of the molecules or to increase the physical stability of the duplex formed between the antisense and sense nucleic acids, e.g., phosphorothioate derivatives and acridine substituted nucleotides can be used. Examples of modified nucleotides which can be used to generate the anti-sense nucleic acid include 5-fluorouracil, 5-bromouracil, 5-chlorouracil, 5-iodouracil, hypoxanthine, xanthine, 4-acetylcytosine, 5-(carboxyhydroxylmethyl) uracil, 5-carboxymethylaminomethyl-2-thiouridine, 5-carboxymethylaminomethyluracil, dihydrouracil, beta-

In addition to naturally-occurring variants of the acetyl-CoA carboxylase sequence that may exist in the population, the skilled artisan will further appreciate that changes can be introduced by mutation into a nucleotide sequence of the polynucleotide encoding acetyl-CoA carboxylase, thereby leading to changes in the amino acid sequence of the encoded acetyl-CoA carboxylase, without altering the functional ability of the acetyl-CoA carboxylase. For example, nucleotide substitutions leading to amino acid substitutions at "non-essential" amino acid residues can be made in a sequence of the polynucleotide encoding acetyl-CoA carboxylase, e.g. SEQ ID NO:2. A "non- essential" amino acid residue is a residue that can be altered from the wild-type sequence of one of the acetyl-CoA carboxylase without altering the activity of said acetyl-CoA carboxylase, whereas an "essential" amino acid residue is required for acetyl-CoA carboxylase activity. Other amino acid residues, however, (e.g., those that are not conserved or only semi-conserved in the domain having acetyl-CoA carboxylase activity) may not be essential for activity and thus are likely to be amenable to alteration without altering acetyl-CoA carboxylase activity.

Accordingly, the invention relates to polynucleotides encoding acetyl-CoA carboxylase that contain changes in amino acid residues that are not essential for acetyl-CoA carboxylase activity. Such acetyl-CoA carboxylase differs in amino acid sequence from a sequence contained in SEQ ID NO:3 yet retain the acetyl-CoA carboxylase activity described herein. The polynucleotide can comprise a nucleotide sequence encoding a polypeptide, wherein the polypeptide comprises an amino acid sequence at least about 60% identical to an amino acid sequence of SEQ ID NO:3 and has acetyl-CoA carboxylase activity. Preferably, the protein encoded by the nucleic acid molecule is at least about 60-65% identical to the sequence in SEQ ID NO:3, more preferably at least about 60-70% identical to one of the sequences in SEQ ID NO:3, even more preferably at least about 70-80%, 80- 90%, 90-95% homologous to the sequence in SEQ ID NO:3, and most preferably at least about 96%, 97%, 98%, or 99% identical to the sequence in SEQ ID NO:3.

To determine the percent homology of two amino acid sequences (e.g., one of the sequence of SEQ ID NO:3 and a mutant form thereof) or of two nucleic acids, the sequences are aligned for optimal comparison purposes (e.g., gaps can be introduced in the sequence of one protein or nucleic acid for optimal alignment with the other protein or nucleic acid). The amino acid residues or nucleotides at corresponding amino acid positions or nucleotide positions are then compared. When a position in one sequence (e.g., one of the sequences of SEQ ID NO:2 or 3) is occupied by the same amino acid residue or nucleotide as the corresponding position in the other sequence (e.g., a mutant form of the sequence selected), then the molecules are homologous at that position (i.e., as used herein amino

biology techniques and the sequence information provided herein. For example, acetyl-CoA carboxylase cDNA can be isolated from a library using all or portion of one of the sequences of the polynucleotide of the present invention as a hybridization probe and standard hybridization techniques. Moreover, a polynucleotide encompassing all or a portion of one of the sequences of the polynucleotide of the present invention can be isolated by the polymerase chain reaction using oligonucleotide primers designed based upon this sequence (e.g., a nucleic acid molecule encompassing all or a portion of one of the sequences of polynucleotide of the present invention can be isolated by the polymerase chain reaction using oligonucleotide primers, e.g. of SEQ ID NO:4, 5, or 6, designed based upon this same sequence of polynucleotide of the present invention. For example, mRNA can be isolated from cells, e.g. *Phaffia* (e.g., by the guanidinium-thiocyanate extraction procedure of Chirgwin et al. and cDNA can be prepared using reverse transcriptase (e.g., Moloney MLV reverse transcriptase or AMV reverse transcriptase available from Promega (Madison, USA)). Synthetic oligonucleotide primers for polymerase chain reaction amplification can be designed based upon one of the nucleotide sequences shown in SEQ ID NO:2. A polynucleotide of the invention can be amplified using cDNA or, alternatively, genomic DNA, as a template and appropriate oligonucleotide primers according to standard PCR amplification techniques. The polynucleotide so amplified can be cloned into an appropriate vector and characterized by DNA sequence analysis. Furthermore, oligonucleotides corresponding to an acetyl-CoA carboxylase nucleotide sequence can be prepared by standard synthetic techniques, e.g., using an automated DNA synthesizer.

The terms "fragment", "fragment of a sequence" or "part of a sequence" means a truncated sequence of the original sequence referred to. The truncated sequence (nucleic acid or protein sequence) can vary widely in length; the minimum size being a sequence of sufficient size to provide a sequence with at least a comparable function and/or activity of the original sequence referred to, while the maximum size is not critical. In some applications, the maximum size usually is not substantially greater than that required to provide the desired activity and/or function(s) of the original sequence.

Typically, the truncated amino acid sequence will range from about 5 to about 60 amino acids in length. More typically, however, the sequence will be a maximum of about 50 amino acids in length, preferably a maximum of about 30 amino acids. It is usually desirable to select sequences of at least about 10, 12 or 15 amino acids, up to maximum of about 20 or 25 amino acids.

The term "epitope" relates to specific immunoreactive sites within an antigen, also known as antigenic determinants. These epitopes can be a linear array of monomers in a polymeric composition - such as amino acids in a protein - or consist of or comprise a more complex secondary or tertiary structure. Those of skill will recognize that all immunogens (i. e., substances capable of eliciting an immune response) are antigens; however, some antigen, such as haptens, are not immunogens but may be made immunogenic by coupling to a carrier molecule. The term "antigen" includes references to a substance to which an antibody can be generated and/or to which the antibody is specifically immunoreactive.

The term "one or several amino acids" relates to at least one amino acid but not more than that number of amino acids which would result in a homology of below 60% identity. Preferably, the identity is more than 70% or 80%, more preferred are 85%, 90% or 95%, even more preferred are 96%, 97%, 98%, or 99% identity.

The term "acetyl-CoA carboxylase" or "acetyl-CoA carboxylase activity" relates to enzymatic activities of a polypeptide as described below or which can be determined in enzyme assay method. Furthermore, polypeptides that are inactive in an assay herein but are recognized by an antibody specifically binding to acetyl-CoA carboxylase, i.e., having one or more acetyl-CoA carboxylase epitopes, are also comprised under the term "acetyl-CoA carboxylase". In these cases activity refers to their immunological activity.

The terms "polynucleotide" and "nucleic acid molecule" also relate to "isolated" polynucleotides or nucleic acids molecules. An "isolated" nucleic acid molecule is one which is separated from other nucleic acid molecules which are present in the natural source of the nucleic acid. Preferably, an "isolated" nucleic acid is free of sequences which naturally flank the nucleic acid (i.e., sequences located at the 5' and 3' ends of the nucleic acid) in the genomic DNA of the organism from which the nucleic acid is derived.

For example, in various embodiments, the PNO polynucleotide can contain less than about 5 kb, 4kb, 3kb, 2kb, 1 kb, 0.5 kb or 0.1 kb of nucleotide sequences which naturally flank the nucleic acid molecule in genomic DNA of the cell from which the nucleic acid is derived (e.g., a *Phaffia* cell). Moreover, the polynucleotides of the present invention, in particular an "isolated" nucleic acid molecule, such as a cDNA molecule, can be substantially free of other cellular material, or culture medium when produced by recombinant techniques, or chemical precursors or other chemicals when chemically synthesized.

D-galactosylqueosine, inosine, N6-isopentenyladenine, 1-methylguanine, 1-methylinosine, 2,2-dimethylguanine, 2-methyladenine, 2-methylguanine, 3-methylcytosine, 5-methylcytosine, N6-adenine, 7-methylguanine, 5-methylaminomethyluracil, 5-methoxyaminomethyl-2-thiouracil, beta-D-mannosylqueosine, 5'-methoxycarboxymethyluracil, 5-methoxyuracil, 2-methylthio-N6-isopentenyladenine, uracil-5-oxyacetic acid (v), wybutoxosine, pseudouracil, queosine, 2-thiocytosine, 5-methyl-2-thiouracil, 2-thiouracil, 4-thiouracil, 5-methyluracil, uracil-5-oxyacetic acid methylester, uracil-5-oxyacetic acid (v), 5-methyl-2-thiouracil, 3-(3-amino-3-N-2-carboxypropyl) uracil, (acp3)w, and 2,6-diaminopurine. Alternatively, the antisense nucleic acid can be produced biologically using an expression vector into which a polynucleotide has been subcloned in an antisense orientation (i.e., RNA transcribed from the inserted polynucleotide will be of an antisense orientation to a target polynucleotide of interest, described further in the following subsection).

The antisense nucleic acid molecules of the invention are typically administered to a cell or generated in situ such that they hybridize with or bind to cellular mRNA and/or genomic DNA encoding an acetyl-CoA carboxylase to thereby inhibit expression of the protein, e.g., by inhibiting transcription and/or translation. The hybridization can be by conventional nucleotide complementarity to form a stable duplex, or, for example, in the case of an antisense nucleic acid molecule which binds to DNA duplexes, through specific interactions in the major groove of the double helix. The anti-sense molecule can be modified such that it specifically binds to a receptor or an antigen expressed on a selected cell surface, e.g., by linking the antisense nucleic acid molecule to a peptide or an antibody which binds to a cell surface receptor or antigen. The antisense nucleic acid molecule can also be delivered to cells using the vectors described herein. To achieve sufficient intracellular concentrations of the antisense molecules, vector constructs in which the antisense nucleic acid molecule is placed under the control of a strong prokaryotic, viral, or eukaryotic including plant promoters are preferred.

The antisense nucleic acid molecule of the invention may, e.g., be an α-anomeric nucleic acid molecule. An α-anomeric nucleic acid molecule forms specific double-stranded hybrids with complementary RNA in which, contrary to the usual β-units, the strands run parallel to each other. The antisense nucleic acid molecule can also comprise a 2'-o-methylribonucleotide or a chimeric RNA-DNA analogue.

Further the antisense nucleic acid molecule of the invention can be a ribozyme. Ribozymes are catalytic RNA molecules with ribonuclease activity which are capable of cleaving a

single-stranded nucleic acid, such as a mRNA, to which they have a complementary region. Thus, ribozymes (e.g., hammerhead ribozymes) can be used to catalytically cleave acetyl-CoA carboxylase mRNA transcripts to thereby inhibit translation of mRNA. A ribozyme having specificity for an acetyl-CoA carboxylase-encoding nucleic acid molecule can be designed based upon the nucleotide sequence of an acetyl-CoA carboxylase cDNA disclosed herein or on the basis of a heterologous sequence to be isolated according to methods taught in this invention. For example, a derivative of a Tetrahymena L-19 IVS RNA can be constructed in which the nucleotide sequence of the active site is complementary to the nucleotide sequence to be cleaved in an encoding mRNA (see, e.g., US 4,987,071 and US 5,116,742). Alternatively, acetyl-CoA carboxylase mRNA can be used to select a catalytic RNA having a specific ribonuclease activity from a pool of RNA molecules.

The application of the antisense method to construct a carotenoid overproducing strain from *P. rhodozyma* is disclosed in EP 1,158,051.

In one embodiment the present invention relates to a method of making a recombinant host cell comprising introducing the vector or the polynucleotide of the present invention into a host cell.

Vector DNA can be introduced into prokaryotic or eukaryotic cells via conventional transformation or transfection techniques. As used herein, the terms "transformation" and "transfection", conjugation and transduction are intended to refer to a variety of art-recognized techniques for introducing foreign nucleic acid (e.g., DNA) into a host cell, including calcium phosphate or calcium chloride co-precipitation, DEAE-dextran-mediated transfection, lipofection, natural competence, chemical-mediated transfer, or electroporation. Suitable methods for transforming or transfecting host cells including plant cells are known to the skilled artisan.

For stable transfection of mammalian cells, only a small fraction of cells may integrate the foreign DNA into their genome, depending upon the expression vector and transfection technique used. In order to identify and select these integrants, a gene that encodes a selectable marker (e.g., resistance to antibiotics) is generally introduced into the host cells along with the gene of interest. Preferred selectable markers include those which confer resistance to drugs, such as G418, hygromycin and methotrexate. Nucleic acid encoding a selectable marker can be introduced into a host cell on the same vector as that encoding the polypeptide of the present invention or can be introduced on a separate vector. Cells stably transfected with the introduced nucleic acid can be identified by, for example, drug

this invention, a cDNA pool was used as a template in this PCR cloning of cDNA. The said cDNA pool consists of various cDNA species which were synthesized *in vitro* by the viral reverse transcriptase and Taq polymerase (CapFinder Kit manufactured by Clontech, Palo Alto, U.S.A.) by using the mRNA obtained from *P. rhodozyma* as a template. cDNA of interest thus obtained was confirmed in its sequence. Furthermore, cDNA thus obtained was used for a confirmation of its enzyme activity after the cloning of the cDNA fragment into an expression vector which functions in *E. coli* under the strong promoter activity such as the *lac* or T7 expression system.

In another embodiment, the present invention relates to a method for making a recombinant vector comprising inserting a polynucleotide of the invention into a vector.

Further, the present invention relates to a recombinant vector containing the polynucleotide of the invention or produced by said method of the invention.

As used herein, the term "vector" refers to a nucleic acid molecule capable of transporting a polynucleotide to which it has been linked. One type of vector is a "plasmid", which refers to a circular double stranded DNA loop into which additional DNA segments can be ligated. Another type of vector is a viral vector, wherein additional DNA or PNA segments can be ligated into the viral genome. Certain vectors are capable of autonomous replication in a host cell into which they are introduced (e.g., bacterial vectors having a bacterial origin of replication and episomal mammalian vectors). Other vectors (e.g., non-episomal mammalian vectors) are integrated into the genome of a host cell upon introduction into the host cell, and thereby are replicated along with the host genome. Moreover, certain vectors are capable of directing the expression of genes to which they are operatively linked. Such vectors are referred to herein as "expression vectors". In general, expression vectors of utility in recombinant DNA techniques are often in the form of plasmids. In the present specification, "plasmid" and "vector" can be used interchangeably as the plasmid is the most commonly used form of vector. However, the invention is intended to include such other forms of expression vectors, such as viral vectors (e.g., replication defective retroviruses, adenoviruses and adeno-associated viruses), which serve equivalent functions.

The present invention also relates to cosmids, viruses, bacteriophages and other vectors used conventionally in genetic engineering that contain a nucleic acid molecule according to the invention. Methods which are well known to those skilled in the art can be used to construct various plasmids and vectors. Alternatively, the nucleic acid molecules and vectors of the invention can be reconstituted into liposomes for delivery to target cells.

Expression of proteins in prokaryotes is most often carried out with vectors containing constitutive or inducible promoters directing the expression of either fusion or non-fusion proteins. Fusion vectors add a number of amino acids to a protein encoded therein, usually to the amino terminus of the recombinant protein but also to the C-terminus or fused within suitable regions in the proteins. Such fusion vectors typically serve three purposes: 1) to increase expression of recombinant protein; 2) to increase the solubility of the recombinant protein; and 3) to aid in the purification of the recombinant protein by acting as a ligand in affinity purification. Often, in fusion expression vectors, a proteolytic cleavage site is introduced at the junction of the fusion moiety and the recombinant protein to enable separation of the recombinant protein from the fusion moiety subsequent to purification of the fusion protein. Such enzymes, and their cognate recognition sequences, include Factor Xa, thrombin and enterokinase.

Typical fusion expression vectors include pGEX (Pharmacia Biotech Inc.), pMAL (New England Biolabs, Beverly, USA) and pRIT5 (Pharmacia, Piscataway, USA) which fuse glutathione S-transferase (GST), maltose E binding protein, or protein A, respectively, to the target recombinant protein. In one embodiment, the coding sequence of the polypeptide encoded by the polynucleotide of the present invention is cloned into a pGEX expression vector to create a vector encoding a fusion protein comprising, from the N-terminus to the C-terminus, GST-thrombin cleavage site-X protein. The fusion protein can be purified by affinity chromatography using glutathione-agarose resin, e.g. recombinant acetyl-CoA carboxylase unfused to GST can be recovered by cleavage of the fusion protein with thrombin.

Examples of suitable inducible non-fusion *E. coli* expression vectors include pTrc and pET 11d. Target gene expression from the pTrc vector relies on host RNA polymerase transcription from a hybrid trp-lac fusion promoter. Target gene expression from the pET 11d vector relies on transcription from a T7 *gn10*-lac fusion promoter mediated by a coexpressed viral RNA polymerase (T7 *gn1*). This viral polymerase is supplied by host strains BL21(DE3) or HMS174(DE3) from a resident λ prophage harboring a T7 *gn1* gene under the transcriptional control of the *lac*UV 5 promoter.

One strategy to maximize recombinant protein expression is to express the protein in host bacteria with an impaired capacity to proteolytically cleave the recombinant protein. Another strategy is to alter the nucleic acid sequence of the nucleic acid to be inserted into an expression vector so that the individual codons for each amino acid are those preferentially

reaction mixture contained 50 mM Tris, pH 7.5, 6 µM acetyl-CoA, 2 mM ATP, 7 mM $KHCO_3$, 8 mM $MgCl_2$, 1 mM dithiothreitol, and 1 mg/ml bovine serum albumin. Enzyme is preincubated (30 min, 25°C) with bovine serum albumin (2 mg/ml) and potassium citrate (10 mM). Reactions are initiated by transferring 50 µl of preincubated enzyme to the reaction mixture (final volume 200 µl) and incubated for 5-20 min at 25°C. Reactions are terminated by addition of 50 µl 10% perchloric acid. Following termination of the reaction, the samples are centrifuged (3 min, 10,000 × g) and analyzed by HPLC. A mobile phase of 10 mM KH_2PO_4, pH 6.7 (solvent A), and MeOH (solvent B) is used. The flow rate is 1.0 ml/min, and the gradient is as follows: hold at 100% solvent A for 1 min followed by a linear gradient to 30% solvent B over the next 5 min, then hold at 30% solvent B for 5 min. Using this method the retention times were 7.5 and 9.0 min for malonyl-CoA and acetyl-CoA, respectively. When an expression vector for *S. cerevisiae* is used, a complementation analysis can be conveniently exploited by using conditional acetyl-CoA carboxylase null mutant strain derived from *S. cerevisiae* as a host strain for its confirmation of activity.

Succeeding to the confirmation of the enzyme activity, an expressed protein would be purified and used for raising the antibody against the purified enzyme. Antibody thus prepared would be used for a characterization of the expression of the corresponding enzyme in a strain improvement study, an optimization study of the culture condition, and the like.

In a further embodiment, the present invention relates to an antibody that binds specifically to the polypeptide of the present invention or parts, i.e. specific fragments or epitopes of such a protein.

The antibodies of the invention can be used to identify and isolate other acetyl-CoA carboxylase and genes. These antibodies can be monoclonal antibodies, polyclonal antibodies or synthetic antibodies as well as fragments of antibodies, such as Fab, Fv or scFv fragments etc. Monoclonal antibodies can be prepared, for example, by the techniques as originally described by Kohler and Milstein, which comprise the fusion of mouse myeloma cells to spleen cells derived from immunized mammals.

Furthermore, antibodies or fragments thereof to the aforementioned peptides can be obtained by using methods known to the skilled person. These antibodies can be used, for example, for the immunoprecipitation and immunolocalization of proteins according to the invention as well as for the monitoring of the synthesis of such proteins, for example, in recombinant organisms, and for the identification of compounds interacting with the

protein according to the invention. For example, surface plasmon resonance as employed in the BIAcore system can be used to increase the efficiency of phage antibodies selections, yielding a high increment of affinity from a single library of phage antibodies which bind to an epitope of the protein of the invention. In many cases, the binding phenomenon of antibodies to antigens is equivalent to other ligand/anti-ligand binding.

In this invention, the gene fragment for acetyl-CoA carboxylase was cloned from *P. rhodozyma* with a purpose to decrease its expression level in *P. rhodozyma* by genetic method using the cloned gene fragment.

To decrease a gene expression with genetic methods, some strategies can be employed, one of which is a gene-disruption method. In this method, a partial fragment of the objective gene to be disrupted is ligated to a drug resistant cassette on the integration vector which can not replicate in the host organism. A drug resistance gene which encodes the enzyme that enables the host to survive in the presence of a toxic antibiotic is often used for the selectable marker. G418 resistance gene harbored in pGB-Ph9 (Wery *et al.* (Gene, 184, 89-97, 1997)) is an example of a drug resistance gene which functions in *P. rhodozyma*. Nutrition complementation marker can be also used in the host which has an appropriate auxotrophy marker. *P. rhodozyma* ATCC24221 strain that requires cytidine for its growth is one example of the auxotroph. By using CTP synthetase as donor DNA for ATCC24221, a host vector system using a nutrition complementation can be established.

After the transformation of the host organisms and recombination between the objective gene fragment on the vector and its corresponding gene fragment on the chromosome of the host organisms, the integration vector is integrated onto the host chromosome by single cross recombination. As a result of this recombination, the drug resistant cassette would be inserted in the objective gene whose translated product is only synthesized in its truncated form which does not have its enzymatic function. In a similar manner, two parts of the objective gene were also used for gene disruption study in which the drug resistant gene can be inserted between such two partial fragments of the objective genes on the integration vector. In the case of this type of vector, double recombination event between the gene fragments harbored on the integration vector and the corresponding gene fragments on the chromosome of the host are expected. Although frequency of this double crossing-over recombination is lower than single cross recombination, null phenotype of the objective gene by the double cross recombination is more stable than by the single cross recombination.

On the other hand, this strategy has difficulty in the case of the gene whose function is essential and disruption is lethal for the host organism such as acetyl-CoA carboxylase gene. The function of acetyl-CoA carboxylase is indispensable for the host survival other than the biosynthesis of fatty acid. From such a viewpoint, it seemed to be difficult to construct the acetyl-CoA carboxylase disruptant from *P. rhodozyma* by this gene disruption method.

In such a case, other strategies can be applied to decrease (not to disrupt) a gene expression, one of which is a conventional mutagenesis to screen the mutant whose expression for acetyl-CoA carboxylase is decreased. In this method, an appropriate recombinant in which an appropriate reporter gene is fused to the promoter region of acetyl-CoA carboxylase gene from the host organism is mutated and mutants which show a weaker activity of reporter gene product can be screened. In such mutants, it is expected that their expression of acetyl-CoA carboxylase activity decreased by the mutation lying in the promoter region of reporter gene or *trans*-acting region which might affect the expression of acetyl-CoA carboxylase gene other than the mutation lying in the promoter gene itself. In the case of mutation occurring at the promoter region of the reporter fusion, such mutation can be isolated by the sequence of the corresponding region. Thus isolated mutation can be introduced in a variety of carotenoids, especially astaxanthin producing mutants derived from *P. rhodozyma* by a recombination between the original promoter for acetyl-CoA carboxylase gene on the chromosome and the mutated promoter fragment. To exclude mutations occurring at a *trans*-acting region, a mutation can also be induced by an *in vitro* mutagenesis of a *cis* element in the promoter region. In this approach, a gene cassette, containing a reporter gene which is fused to a promoter region derived from a gene of interest at its 5'-end and a terminator region from a gene of interest at its 3'-end, is mutagenized and then introduced into *P. rhodozyma*. By detecting the difference of the activity of the reporter gene, an effective mutation can be screened. Such a mutation can be introduced in the sequence of the native promoter region on the chromosome by the same method as the case of an *in vivo* mutation approach. But, these methods have some drawbacks to have some time-consuming process.

Another strategy to decrease a gene expression is an antisense method. This method is frequently applied to decrease the gene expression even when teleomorphic organisms such as *P. rhodozyma* are used as host organisms, to which the mutation and gene disruption method is usually difficult to be applied. The anti-sense method is a method to decrease an expression of gene of interest by introducing an artificial gene fragment, whose sequence is complementary to cDNA fragment of the gene of interest. Such an anti-sense

extrachromosomally. In this respect, it is also to be understood that the nucleic acid molecule of the invention can be used to restore or create a mutant gene via homologous recombination.

Accordingly, in another embodiment the present invention relates to a host cell genetically engineered with the polynucleotide of the invention or the vector of the invention.

The terms "host cell" and "recombinant host cell" are used interchangeably herein. It is understood that such terms refer not only to the particular subject cell but to the progeny or potential progeny of such a cell. Because certain modifications may occur in succeeding generations due to either mutation or environmental influences, such progeny may not, in fact, be identical to the parent cell, but are still included within the scope of the term as used herein.

For example, a polynucleotide of the present invention can be introduced in bacterial cells as well as insect cells, fungal cells or mammalian cells (such as Chinese hamster ovary cells (CHO) or COS cells), algae, ciliates, plant cells, fungi or other microorganims like *E. coli*. Other suitable host cells are known to those skilled in the art. Preferred are *E. coli*, baculovirus, Agrobacterium or fungal cells are, for example, those of the genus *Saccharomyces*, e.g. those of the species *S. cerevisiae* or *P. rhodozyma* (*Xanthophylomyces dendrorhous*).

In addition, in one embodiment, the present invention relates to a method for the production of fungal transformants comprising the introduction of the polynucleotide or the vector of the present invention into the genome of said fungal cell.

For the expression of the nucleic acid molecules according to the invention in sense or antisense orientation in plant cells, the molecules are placed under the control of regulatory elements which ensure the expression in fungal cells. These regulatory elements may be heterologous or homologous with respect to the nucleic acid molecule to be expressed as well with respect to the fungal species to be transformed.

In general, such regulatory elements comprise a promoter active in fungal cells. To obtain constitutive expression in fungal cells, preferably constitutive promoters are used, e.g., the glyceraldehyde-3-dehydrogenase promoter derived from *P. rhodozyma* (WO 97/23,633). Inducible promoters may be used in order to be able to exactly control expression. An example for inducible promoters is the promoter of genes encoding heat shock proteins. Also an amylase gene promoter which is a candidate for such inducible promoters has been described (EP 1,035,206). The regulatory elements may further comprise transcriptional and/or translational enhancers functional in fungal cells. Furthermore, the regula-

selection (e.g., cells that have incorporated the selectable marker gene will survive, while the other cells die).

To create a homologous recombinant microorganism, a vector is prepared which contains at least a portion of the polynucleotide of the present invention into which a deletion, addition or substitution has been introduced to thereby alter, e.g., functionally disrupt, the acetyl-CoA carboxylase gene. Preferably, this acetyl-CoA carboxylase gene is a *P. rhodozyma* acetyl-CoA carboxylase gene, but it can be a homologue from a related or different source. Alternatively, the vector can be designed such that, upon homologous recombination, the endogenous acetyl-CoA carboxylase gene is mutated or otherwise altered but still encodes a functional protein (e.g., the upstream regulatory region can be altered to thereby alter the expression of the endogenous acetyl-CoA carboxylase). To create a point mutation via homologous recombination also DNA-RNA hybrids can be used known as chimeraplasty known from Cole-Strauss *et al.*, Nucl. Aci. Res., 27, 5, 1323-1330, 1999 and Kmiec, Gene therapy., American Scientist. 87, 3, 240-247. 1999.

The vector is introduced into a cell and cells in which the introduced polynucleotide gene has homologously recombined with the endogenous acetyl-CoA carboxylase gene are selected, using art-known techniques.

Further host cells can be produced which contain selection systems which allow for regulated expression of the introduced gene. For example, inclusion of the polynucleotide of the invention on a vector placing it under control of the lac operon permits expression of the polynucleotide only in the presence of IPTG. Such regulatory systems are well known in the art.

Preferably, the introduced nucleic acid molecule is foreign to the host cell.

By "foreign" it is meant that the nucleic acid molecule is either heterologous with, respect to the host cell, this means derived from a cell or organism with a different genomic background, or is homologous with respect to the host cell but located in a different genomic environment than the naturally occurring counterpart of said nucleic acid molecule. This means that, if the nucleic acid molecule is homologous with respect to the host cell, it is not located in its natural location in the genome of said host cell; in particular it is surrounded by different genes. In this case the nucleic acid molecule may be either under the control of its own promoter or under the control of a heterologous promoter. The vector or nucleic acid molecule according to the invention which is present in the host cell may either be integrated into the genome of the host cell or it may be maintained in some form

tory elements may include transcription termination signals, such as a poly-A signal, which lead to the addition of a poly A tail to the transcript which may improve its stability.

Methods for the introduction of foreign DNA into fungal cells are also well known in the art. These include, for example, transformation with the LiCl method, the fusion of protoplasts, electroporation, biolistic methods like particle bombardment other methods known in the art. Methods for the transformation using biolistic methods are well known to the person skilled in the art.

The term "transformation" as used herein, refers to the transfer of an exogenous polynucleotide into a host cell, irrespective of the method used for the transfer. The polynucleotide may be transiently or stably introduced into the host cell and may be maintained non- integrated, for example, as a plasmid or as chimeric links, or alternatively, may be integrated into the host genome.

In general, the fungi which can be modified according to the invention and which either show overexpression of a protein according to the invention or a reduction of the synthesis of such a protein can be derived from any desired fungal species.

Further, in one embodiment, the present invention relates to a fungal cell comprising the polynucleotide the vector or obtainable by the method of the present invention.

Thus, the present invention relates also to transgenic fungal cells which contain (preferably stably integrated into the genome) a polynucleotide according to the invention linked to regulatory elements which allow expression of the polynucleotide in fungal cells and wherein the polynucleotide is foreign to the transformed fungal cell. For the meaning of foreign; see supra.

Thus, the present invention also relates to transformed fungal cells according to the invention.

Accordingly, due to the altered expression of acetyl-CoA carboxylase, cells metabolic pathways are modulated in yield production, and/or efficiency of production.

The terms "production" or "productivity" are art-recognized and include the concentration of the fermentation product (for example fatty acids, carotenoids, (poly)saccharides, lipids, vitamins, isoprenoids, wax esters, and/or polymers like polyhydroxyalkanoates and/or its metabolism products or further desired fine chemical as mentioned herein) formed within a given time and a given fermentation volume (e.g., kg product per hour per liter).

The term "efficiency" of production includes the time required for a particular level of production to be achieved (for example, how long it takes for the cell to attain a particular rate of output of a said altered yield, in particular, into carotenoids, (poly)saccharides, lipids, vitamins, isoprenoids etc.).

The term "yield" or "product/carbon yield" is art-recognized and includes the efficiency of the conversion of the carbon source into the product (i.e. acetyl CoA, fatty acids, vitamins, carotenoids, isoprenoids, lipids etc. and/or further compounds as defined above and which biosynthesis is based on said products). This is generally written as, for example, kg product per kg carbon source. By increasing the yield or production of the compound, the quantity of recovered molecules, or of useful recovered molecules of that compound in a given amount of culture over a given amount of time is increased.

The terms "biosynthesis" (which is used synonymously for "synthesis" of "biological production" in cells, tissues plants, etc.) or a "biosynthetic pathway" are art-recognized and include the synthesis of a compound, preferably an organic compound, by a cell from intermediate compounds in what may be a multistep and highly regulated process.

The language "metabolism" is art-recognized and includes the totality of the biochemical reactions that take place in an organism. The metabolism of a particular compound, then, (e.g., the metabolism of acetyl CoA, a fatty acid, hexose, isoprenoid, vitamin, carotenoid, lipid etc.) comprises the overall biosynthetic, modification, and degradation pathways in the cell related to this compound.

Such a genetically engineered *P. rhodozyma* would be cultivated in an appropriate medium and evaluated in its productivity of carotenoids, especially astaxanthin. A hyper producer of astaxanthin thus selected would be confirmed in view of the relationship between its productivity and the level of gene or protein expression which is introduced by such a genetic engineering method.

The present invention is further illustrated with Examples described below.

The following materials and methods employed in the Examples are described below:

Strains

P. rhodozyma ATCC96594 (re-deposited under the accession No. ATCC 74438 on April 8, 1998 pursuant to the Budapest Treaty)

E. coli DH5α: F⁻, ϕ80d, *lac*ZΔM15, Δ(*lac*ZYA-*arg*F)U169, *hsd* (r_K^-; m_K^+), *rec*A1, *end*A1, *deo*R, *thi*-1, *sup*E44, *gyr*A96, *rel*A1 (Toyobo, Osaka, Japan)

Isolation of total RNA from *P. rhodozyma* was performed with the phenol method by using Isogen (Nippon Gene, Toyama, Japan). mRNA was purified from total RNA thus obtained by using mRNA separation kit (Clontech). cDNA was synthesized by using CapFinder cDNA construction kit (Clontech).

In vitro packaging was performed by using Gigapack III gold packaging extract (Stratagene).

The polymerase chain reaction (PCR) was performed with the thermal cycler from Perkin Elmer model 2400. Each PCR condition is described in examples. PCR primers were purchased from a commercial supplier. Fluorescent DNA primers for DNA sequencing were purchased from Pharmacia. DNA sequencing was performed with the automated fluorescent DNA sequencer (ALFred, Pharmacia).

Competent cells of DH5α were purchased from Toyobo (Japan).

Example 1: Isolation of mRNA from *P. rhodozyma* and construction of cDNA library

To construct cDNA library of *P. rhodozyma*, total RNA was isolated by phenol extraction method right after the cell disruption and the mRNA from *P. rhodozyma* ATCC96594 strain was purified by using mRNA separation kit (Clontech).

At first, Cells of ATCC96594 strain from 10 ml of two-day-culture in YPD medium were harvested by centrifugation (1500 x g for 10 min.) and washed once with extraction buffer (10 mM Na-citrate / HCl (pH 6.2) containing 0.7 M KCl). After suspending in 2.5 ml of extraction buffer, the cells were disrupted by French press homogenizer (Ohtake Works Corp., Tokyo, Japan) at 1500 kgf/cm2 and immediately mixed with two times of volume of isogen (Nippon gene) according to the method specified by the manufacturer. In this step, 400 μg of total RNA was recovered.

Then, this total RNA was purified by using mRNA separation kit (Clontech) according to the method specified by the manufacturer. Finally, 16 μg of mRNA from *P. rhodozyma* ATCC96594 strain was obtained.

To construct cDNA library, CapFinder PCR cDNA construction kit (Clontech) was used according to the method specified by the manufacturer. One μg of purified mRNA was applied for a first strand synthesis followed by PCR amplification. After this amplification by PCR, 1 mg of cDNA pool was obtained.

Example 2: Cloning of a partial *ACC* (acetyl-CoA carboxylase) gene from *P. rhodozyma*

E. coli XL1-Blue MRF': Δ(*mcr*A)183, Δ(*mcr*CB-*hsd*SMR-*mrr*)173, *end*A1, *sup*E44, *thi*-1, *rec*A1, *gyr*A96, *rel*A1, *lac* [F' *pro*AB, *lac*IqZΔM15, Tn10 (tet^r)] (Stratagene, La Jolla, USA)

E. coli SOLR: e14-(*mcr*A), Δ(*mcr*CB-*hsd*SMR-*mrr*)171, *sbc*C, *rec*B, *rec*J, *umu*C :: Tn5(kan^r), *uvr*C, *lac*, *gyr*A96, *rel*A1, *thi*-1, *end*A1, ΔR, [F' *pro*AB, *lac*IqZ ΔM15] Su-(nonsuppressing) (Stratagene)

E. coli TOP10: F-, *mcr*A, Δ*mrr-hsd*RMS-*mcr*BC), *ϕ80*, Δ*lac*Z M15, Δ*lac*X74, *rec*A1, *deo*R, *ara*D139, (*ara-leu*)7697, *gal*U, *gal*K, rpsL (Str^r), *end*A1, *nup*G (Invitrogen, Carlsbad, USA)

Vectors

λZAPII (Stratagene)

pBluescriptII KS- (Stratagene)

pMOSBlue T-vector (Amersham, Buckinghamshire, U.K.)

pCR2.1-TOPO (Invitrogen)

Media

P. rhodozyma strain was maintained routinely in YPD medium (DIFCO, Detroit, U.S.A.). *E. coli* strain was maintained in LB medium (10 g Bacto-trypton, 5 g yeast extract (DIFCO) and 5 g NaCl per liter). NZY medium (5 g NaCl, 2 g $MgSO_4$-$7H_2O$, 5 g yeast extract (DIFCO), 10 g NZ amine type A (WAKO, Osaka, Japan) per liter) is used for λ phage propagation in a soft agar (0.7 % agar (WAKO)). When an agar medium was prepared, 1.5 % of agar (WAKO) was supplemented.

Methods

Restriction enzymes and T4 DNA ligase were purchased from Takara Shuzo (Ohtsu, Japan).

Isolation of a chromosomal DNA from *P. rhodozyma* was performed by using QIAGEN Genomic Kit (QIAGEN, Hilden, Germany) following the protocol supplied by the manufacturer. Mini-prep of plasmid DNA from transformed *E. coli* was performed with the Automatic DNA isolation system (PI-50, Kurabo, Co. Ltd., Osaka, Japan). Midi-prep of plasmid DNA from an *E. coli* transformant was performed by using QIAGEN column (QIAGEN). Isolation of λ DNA was performed by Wizard lambda preps DNA purification system (Promega, Madison, U.S.A.) following the protocol prepared by the manufacturer. A DNA fragment was isolated and purified from agarose by using QIAquick or QIAEX II (QIAGEN). Manipulation of λ phage derivatives was followed by the protocol prepared by the manufacturer (Stratagene).

To clone a partial *ACC* gene from *P. rhodozyma*, a degenerate PCR method was exploited. Species and accession number to database whose sequence for acetyl-CoA carboxylase were used for multiple alignment analysis are as follows.

Arabidopsis thaliana	D34630 (DDBJ)
Emericella nidulans	Y15996 (EMBL)
Gallus gallus	P11029 (Swiss-Prot)
Glycine max	L48995 (GenBank)
Homo sapiens	S41121 (PIR)
Medicago sativa	L25042 (GenBank)
Ovis aries	Q28559 (Swiss-Prot)
Rattus norvegicus	P11497 (Swiss-Prot)
Saccharomyces cerevisiae	Q00955 (Swiss-Prot)
Schizosaccharomyces pombe	P78820 (Swiss-Prot)
Ustilago maydis	S49991 (PIR)

Two mixed primers whose nucleotide sequences were designed and synthesized based on the common sequence of known acetyl-CoA carboxylase genes from other species: acc9 (sense primer) (SEQ ID NO:4) and acc13 (antisense primer) (SEQ ID NO:5) (in the sequences "n" means nucleotides a, c, g or t; "h" means nucleotides a, c or t, "m" means nucleotides a or c, "k" means nucleotides g or t, and "y" means nucleotides c or t). After the PCR reaction of 25 cycles of 95°C for 30 seconds, 45°C for 30 seconds and 72°C for 15 seconds by using ExTaq (Takara Shuzo) as a DNA polymerase and cDNA pool obtained in Example 1 as a template, reaction mixture was applied to agarose gel electrophoresis. One PCR band that had a desired length (0.8 kb) was recovered from the agarose gel and purified by QIAquick (QIAGEN) according to the method by the manufacturer and then ligated to pMOSBlue-T-vector (Amersham). After transformation of competent *E. coli* DH5α, 6 white colonies were selected and plasmids were isolated with Automatic DNA isolation system. As a result of sequencing, it was found that 3 clones had a sequence whose deduced amino acid sequence was similar to known acetyl-CoA carboxylase genes. These isolated cDNA clones were designated as pACC1014 and used for further screening study.

Example 3: Isolation of genomic DNA from *P. rhodozyma*

To isolate a genomic DNA from *P. rhodozyma*, QIAGEN genomic kit was used according to the method specified by the manufacturer.

At first, cells of *P. rhodozyma* ATCC96594 strain from 100 ml of overnight culture in YPD medium were harvested by centrifugation (1500 x g for 10 min.) and washed once with TE buffer (10 mM Tris / HCl (pH 8.0) containing 1 mM EDTA). After suspending in 8 ml of Y1 buffer of the QIAGEN genomic kit, lyticase (SIGMA, St. Louis, U.S.A.) was added at the concentration of 2 mg/ml to disrupt cells by enzymatic degradation and the reaction mixture was incubated for 90 min at 30°C and then proceeded to the next extraction step. Finally, 20 µg of genomic DNA was obtained.

Example 4: Southern blot hybridization by using pACC1014 as a probe

Southern blot hybridization was performed to clone a genomic fragment which contains *ACC* gene from *P. rhodozyma*. Two µg of genomic DNA was digested by *Eco*RI and subjected to agarose gel electrophoresis followed by acidic and alkaline treatment. The denatured DNA was transferred to nylon membrane (Hybond N+, Amersham) by using transblot (Joto Rika, Tokyo, Japan) for an hour. The DNA which was transferred to nylon membrane was fixed by a heat treatment (80°C, 90 min). A probe was prepared by labeling a template DNA (*Eco*RI and *Sal*I -digested pACC1014) with DIG multipriming method (Boehringer Mannheim). Hybridization was performed with the method specified by the manufacturer. As a result, a hybridized band was visualized in the range from 2.0 to 2.3 kilobases (kb).

Example 5: Cloning of a genomic fragment containing the *ACC* gene

4 µg of the genomic DNA were digested by *Eco*RI and subjected to agarose gel electrophoresis. Then, DNAs with a length within the range from 1.5 to 2.7 kb was recovered by QIAEX II gel extraction kit (QIAGEN) according to the method specified by the manufacturer. The purified DNA was ligated to 0.5 µg of *Eco*RI-digested and CIAP (calf intestine alkaline phosphatase)-treated λZAP II (Stratagene) at 16°C overnight, and packaged by Gigapack III gold packaging extract (Stratagene). The packaged extract was infected to *E. coli* MRF' strain and over-laid with NZY medium poured onto LB agar medium. About 5000 plaques were screened by using *Eco*RI and *Sal*I-digested pACC1014 as a probe. Five plaques were hybridized to the labeled probe.

The *in vivo* excision protocol was applied to these λZAP II derivatives containing putative *ACC* gene from *P. rhodozyma* by following the instruction manual (Stratagene) to clone the insert fragment into *E. coli* cloning vector, pBluescript SK. Each clone recovered from five positive plaques was subjected for sequencing analysis and it was found that the three of them had the identical sequence to the insert fragment of pACC1014. One of the clone

revealed that this clone contained 5' fragment of *ACC* gene as a result of BLAST X analysis. This clone was named as pACCPvu126 and used for further study.

Example 10: Southern blot hybridization by using pACCPvu126 as a probe

Southern blot hybridization was performed to clone a genomic fragment which covered 5' end of *ACC* gene from *P. rhodozyma*. In a similar manner as Example 7, Southern blot hybridization was performed. A probe was prepared by labeling a template DNA (*Eco*RI - digested pACCPvu116) with DIG multipriming method (Boehringer Mannheim). Hybridization was performed with the method specified by the manufacturer. As a result, a hybridized band whose size was close to 5.0 kb was visualized.

Example 11: Cloning of the genomic clone covering 5' end of *ACC* gene

In a similar manner to Example 8, the genomic fragment containing the insert fragment in pACCPvu126 was cloned by plaque hybridization. The genomic library covering 2.7 to 6.0 kb in length prepared in Example 8 was also used. Twelve positive plaques which hybridized to the insert fragment of pACCPvu126 labeled with DIG were isolated and subjected to in vivo excision to obtain plasmid DNA. As a result of sequencing for thus isolated plasmids, most of the plasmids had the identical sequence to the insert fragment of pACCPvu126. One of the clones was named as pACC204 and used for further study.

Example 12: Cloning of the gapped region between pACC204 and pACC127-17-0.9

As a result of BLAST X analysis against known acetyl-CoA carboxylase genes succeeding to the sequencing study of 3' end of the insert fragment in pACC204 and 5' end of the insert fragment in pACC127-17-0.9, it was suggested that an approximately 0.3 kb fragment could be still missing for a coverage of the entire *ACC* gene. The following PCR primers were synthesized based on the internal sequence of pACC204 and pACC127-17-0.9: acc43 (sense primer) (SEQ ID NO:9) and acc44 (antisense primer) (SEQ ID NO:10). After the PCR reaction of 25 cycles of 94°C for 15 seconds, 55°C for 30 seconds and 72°C for 15 seconds by using HF polymerase (Clontech) as a DNA polymerase and a genomic DNA obtained in Example 3 as a template, the reaction mixture was applied to agarose gel electrophoresis. One PCR band that had a desired length (0.3 kb) was recovered from the agarose gel and purified by QIAquick (QIAGEN) according to the method by the manufacturer and then cloned into pCR2.1-TOPO (Invitrogen). After transformation of competent *E. coli* TOP10, 6 white colonies were selected and plasmids were isolated with Automatic DNA isolation system. As a result of sequencing, it was found that 5 clones had an

DNA was digested by *Eco*RI and subjected to agarose gel electrophoresis. Then, DNAs with a length within the following range were recovered by QIAEX II gel extraction kit (QIAGEN) according to the method specified by the manufacturer: (1) from 2.7 to 5.0 kb; (2) from 1.4 to 2.7 kb; and (3) from 0.5 to 1.4 kb.

Each purified DNA was ligated to 0.5 μg of *Eco*RI-digested and CIAP (calf intestine alkaline phosphatase)-treated λZAP II (Stratagene) at 16 °C overnight, and packaged by Gigapack III gold packaging extract (Stratagene). The packaged extract was infected to *E. coli* MRF' strain and over-laid with NZY medium poured onto LB agar medium. About 5000 plaques were screened by using *Eco*RI-digested pACCStu107 and pACCPvd107 as probes. The following candidates were isolated after plaque hybridization study.

1) 3 plaques from the 2.7 to 6.0 kb library by using the insert of pACCPvd107 as a probe.
2) 3 plaques from the 1.4 to 2.7 kb library by using the insert of pACCStu107 as a probe.
3) 21 plaques from the 0.5 to 1.4 kb library by using the insert of pACCStu107 as a probe.

The *in vivo* excision protocol was applied to these λZAP II derivatives containing putative *ACC* gene from *P. rhodozyma* by following the instruction manual (Stratagene) to clone the insert fragment into *E. coli* cloning vector, pBluescript SK. Each clone recovered from the positive plaques was subjected for sequencing analysis. At least each clone had the putative *ACC* gene from BLAST X analysis (http://www.blast.genome.ad.jp/). The following clones were selected and used for further analysis:

pACC119-18 having a 6 kb insert and covering the 3' end of the *ACC* gene;
pACC119-17-0.6 having a 0.6 kb insert flanking the 5' end of the pACC1224 insert fragment;
pACC119-17-2 having a 2 kb insert flanking the 5' end of the pACC119-17-0.6 insert fragment; and
pACC127-17-0.9 having a 0.9kb insert flanking the 5' end of the pACC119-17-2 insert fragment.

As a result of whole sequencing of the entire region of insert fragment in pACC119-18, pACC119-17-0.6, pACC119-17-2 and pACC127-17-0.9, it was suggested that these clones did not cover the 5' end of the *ACC* gene.

Example 9: Cloning of the franking region of the insert fragment in pACC127-17-0.9 from the genome of *P. rhodozyma* by genome walking method

PCR primer acc26 (SEQ ID NO:8) was synthesized based on the internal sequence of pACC127-17-0.9 and used for genome walking method.

In the PCR reaction using acc26 primer, a 2.6 kb PCR band emerged from the genomic *Pvu*II library. This PCR band was cloned into pCR2.1-TOPO (Invitrogen) and it was

was named as pACC1224 and used for further study. As a result of whole sequencing of the entire region of insert fragment in pACC1224, it was suggested that this clone contained neither its 5'- nor 3'-end of the *ACC* gene.

Example 6: Cloning of the flanking region of the insert fragment in pACC1224 from the genome of *P. rhodozyma* by genome walking method

Two PCR primers were synthesized based on the internal sequence of pACC1224 and used for the genome walking method: acc17 (SEQ ID NO:6) and acc18 (SEQ ID NO:7). The protocol of the instruction manual provided from the supplier (Clontech) was followed for the genome walking method. In the PCR reaction using acc17 primer, a 2.8 kb PCR band emerged from the genomic *Stu*I library. In the case of acc18 primer, a 2.2 kb PCR band was produced in the genomic *Pvu*II library. These PCR bands were cloned into pCR2.1-TOPO (Invitrogen) and it was revealed that 2.8 kb PCR band contained a 5' fragment of *ACC* gene and 2.2 kb PCR band contained 3' fragment of *ACC* gene, respectively. The clones containing 2.8 kb and 2.2 kb PCR fragment were named as pACCStu107 and pACCPvd107, respectively and used for further study.

Example 7: Southern blot hybridization by using pACCStu107 and pACCPvd107 as probes

Southern blot hybridization was performed to clone a genomic fragment which covered the *ACC* gene from *P. rhodozyma*. 2 µg of genomic DNA was digested by *Eco*RI and subjected to agarose gel electrophoresis followed by acidic and alkaline treatment. The denatured DNA was transferred to nylon membrane (Hybond N+, Amersham) by using transblot (Joto Rika, Tokyo, Japan) for an hour. The DNA which was transferred to nylon membrane was fixed by a heat treatment (80°C, 90 min). A probe was prepared by labeling a template DNA (*Eco*RI -digested pACCStu107 and pACCPvd107) with the DIG multi-priming method (Boehringer Mannheim). Hybridization was performed with the method specified by the manufacturer. As a result, several hybridized bands whose size was close to 2.0 kb, 0.9 kb and 0.6 kb were visualized when the insert fragment in pACCStu107 was used as a probe. In the case that the insert fragment in pACCPvd107 was used as a probe, a hybridized band was visualized in the range from 6.0 kb to 6.5 kb.

Example 8: Cloning of the genomic clone covering the *ACC* gene

In a similar manner to Example 5, the genomic fragment containing the insert fragment in pACCStu107 and pACCPvd107 was cloned by plaque hybridization. 4 µg of the genomic

Then, 3.1 kb of the *SacI* fragment containing ribosomal DNA (rDNA) locus (Wery et al., Gene, 184, 89-97, 1997) is inserted downstream of the G418 cassette on thus prepared plasmid. The rDNA fragment exists in multicopies on the chromosome of eukaryote. The integration event via the rDNA fragment would result in multicopied integration onto the chromosome of the host used and this enables the overexpression of foreign genes which are harbored in expression vector.

Subsequently, *ACC* promoter is inserted in the upstream of *ACC* terminator to construct of expression vector which functions in *P. rhodozyma*.

Finally, the antisense *ACC* construct is completed by inserting the 1.5kb of *SfiI* fragment containing antisense *ACC* into thus prepared expression vector functioning in *P. rhodozyma*. A similar plasmid construction is disclosed in EP 1,158,051.

Example 15: Transformation of *P. rhodozyma* with an *ACC*-antisense vector

The *ACC*-antisense vector thus prepared is transformed into *P. rhodozyma* wild type strain, ATCC96594. The protocol for the biolistic transformation is disclosed in EP 1,158,051.

Example 16: Characterization of antisense *ACC* recombinant of *P. rhodozyma*

Antisense *ACC* recombinant of *P. rhodozyma*, ATCC96594 is cultured in 50 ml of YPD medium in 500 ml Erlenmeyer flask at 20°C for 3 days by using their seed culture which grows in 10 ml of YPD medium in test tubes (21 mm in diameter) at 20°C for 3 days. For analysis of carotenoid produced appropriate volume of culture broth is withdrawn and used for analysis of their growth, productivity of carotenoids, especially astaxanthin. For analysis of growth, optical density at 660 nm is measured by using a UV-1200 photometer (Shimadzu Corp., Kyoto, Japan) in addition to the determination of their dried cell mass by drying up the cells derived from 1 ml of broth after microcentrifugation at 100°C for one day. For the analysis of the content of astaxanthin and total carotenoids, cells are harvested from 1.0 ml of broth after microcentrifugation and used for the extraction of the carotenoids from cells of *P. rhodozyma* by disruption with glass beads. After extraction, disrupted cells are removed by centrifugation and the resultant is analyzed for carotenoid content with HPLC. The HPLC condition used is as follows: HPLC column: Chrompack Lichrosorb si-60 (4.6 mm, 250 mm), Temperature: room temperature, Eluent: acetone / hexane (18/82) add 1 ml/L of water to eluent, Injection volume: 10 µl, Flow rate: 2.0 ml/min, Detection: UV at 450 nm. A reference sample of astaxanthin can be obtained from Hoffmann La-Roche (Basel, Switzerland).

identical sequence from each other. One of the isolated clones was designated as pACC210.

Example 13: Sequencing of a complete genomic fragment containing *ACC* gene

pACC204, pACC210, pACC127-17-0.9, pACC119-17-2, pACC119-17-0.6, pACC1224 and pACC119-18 were sequenced with primer walking procedure by using AutoRead sequencing kit (Pharmacia).

As a result of sequencing, the nucleotide sequence comprising 10561 base pairs of the genomic fragment containing the *ACC* gene from *P. rhodozyma* containing its promoter (1445 base pairs) and terminator (1030 base pairs) was determined (SEQ ID NO:1). The coding region was 8086 base pairs long and consisted of 19 exons and 18 introns. Introns were dispersed all through the coding region without 5' or 3' bias. It was found that an open reading frame (SEQ ID NO:2) consists of 2187 amino acids (SEQ ID NO:3) whose sequence is strikingly similar to the known amino acid sequence of acetyl-CoA carboxylase from other species (56.28% identity to acetyl-CoA carboxylase from *Emericella nidulans*) as a result of homology search by GENETYX-SV/RC software (Software Development Co., Ltd., Tokyo, Japan).

Fig. 1 depicts a cloned DNA fragment covering *ACC* gene region on the chromosome of *P. rhodozyma*.

Example 14: Construction of antisense plasmid for *ACC* gene

An antisense gene fragment which covers the entire structure gene for *ACC* gene is amplified by PCR and then cloned into an integration vector in which the antisense *ACC* gene is transcribed by its own *ACC* promoter in *P. rhodozyma*.

The primers include an asymmetrical recognition sequence for the restriction enzyme, *Sfi*I (GGCCNNNNNGGCC) but their asymmetrical hang-over sequence is designed to be different. This enables a directional cloning into expression vector which has the same asymmetrical sequence at their ligation sequence. The use of such a construction is disclosed in EP 1,158,051.

For the promoter and terminator fragment which can drive the transcription of the antisense *ACC* gene, the *ACC* promoter and terminator is cloned from the chromosome by using the sequence information listed in SEQ ID NO:1. The *ACC* terminator fragment is fused to a G418 resistant cassette by ligating the DNA fragment containing the *ACC* terminator to a G418 resistant cassette of pG418Sa330 (EP 1,035,206) to an appropriate vector such as pBluescriptII KS- (Stratagene).

Claims

1. An isolated polynucleotide comprising a nucleic acid molecule one or more selected from the group consisting of:

(a) nucleic acid molecules encoding at least the mature form of the polypeptide depicted in SEQ ID NO:3;

(b) nucleic acid molecules comprising the coding sequence as depicted in SEQ ID NO:2;

(c) nucleic acid molecules whose nucleotide sequence is degenerate as a result of the genetic code to a nucleotide sequence of (a) or (b);

(d) nucleic acid molecules encoding a polypeptide derived from the polypeptide encoded by a polynucleotide of (a) to (c) by way of substitution, deletion and/or addition of one or several amino acids of the amino acid sequence of the polypeptide encoded by a nucleotide of (a) to (c);

(e) nucleic acid molecules encoding a polypeptide derived from the polypeptide whose sequence has an identity of 56.3 % or more to the amino acid sequence of the polypeptide encoded by a nucleic acid molecule of (a) or (b);

(f) nucleic acid molecules comprising a fragment encoded by a nucleic acid molecule of any one of (a) to (e) and having acetyl-CoA carboxylase activity;

(g) nucleic acid molecules comprising a polynucleotide having a sequence of a nucleic acid molecule amplified from a *Phaffia* nucleic acid library using the primers depicted in SEQ ID NO:4, 5, and 6;

(h) nucleic acid molecules encoding a polypeptide having acetyl-CoA carboxylase activity, wherein said polypeptide is a fragment of a polypeptide encoded by any one of (a) to (g);

(i) nucleic acid molecules comprising at least 15 nucleotides of a polynucleotide of any one of (a) to (d);

(j) nucleic acid molecules encoding a polypeptide having acetyl-CoA carboxylase activity, wherein said polypeptide is recognized by antibodies that have been raised against a polypeptide encoded by a nucleic acid molecule of any one of (a) to (h);

(k) nucleic acid molecules obtainable by screening an appropriate library under stringent conditions with a probe having the sequence of the nucleic acid molecule of any one of (a) to (j), and encoding a polypeptide having acetyl-CoA carboxylase activity;

(l) nucleic acid molecules whose complementary strand hybridizes under stringent conditions with a nucleic acid molecule of any one of (a) to (k), and encoding a polypeptide having acetyl-CoA carboxylase activity.

2. An isolated polynucleotide comprising a nucleic acid molecule one or more selected from the group consisting of:

(m) nucleic acid molecules comprising the nucleotide sequence as depicted in SEQ ID NO:1;

(n) nucleic acid molecules whose nucleotide sequence is degenerate as a result of the genetic code to a nucleotide sequence of (m);

(o) nucleic acid molecules encoding a polypeptide derived from the polypeptide encoded by a polynucleotide of (m) or (n) by way of substitution, deletion and/or addition of one or several amino acids of the amino acid sequence of the polypeptide encoded by a nucleotide of (m) or (n);

(p) nucleic acid molecules encoding a polypeptide derived from the polypeptide whose sequence has an identity of 56.3 % or more to the amino acid sequence of the polypeptide encoded by a nucleic acid molecule of (m);

(q) nucleic acid molecules comprising a fragment encoded by a nucleic acid molecule of any one of (m) to (p) and having acetyl-CoA carboxylase activity;

(r) nucleic acid molecules comprising a polynucleotide having a sequence of a nucleic acid molecule amplified from a *Phaffia* nucleic acid library using the primers depicted in SEQ ID NO:4, 5, and 6;

(s) nucleic acid molecules encoding a polypeptide having acetyl-CoA carboxylase activity, wherein said polypeptide is a fragment of a polypeptide encoded by any one of (m) to (r);

(t) nucleic acid molecules comprising at least 15 nucleotides of a polynucleotide of any one of (m) to (o);

(u) nucleic acid molecules encoding a polypeptide having acetyl-CoA carboxylase activity, wherein said polypeptide is recognized by antibodies that have been raised against a polypeptide encoded by a nucleic acid molecule of any one of (m) to (s);

(v) nucleic acid molecules obtainable by screening an appropriate library under stringent conditions with a probe having the sequence of the nucleic acid molecule of any one of (m) to (u), and encoding a polypeptide having acetyl-CoA carboxylase activity;

(w) nucleic acid molecules whose complementary strand hybridizes under stringent conditions with a nucleic acid molecule of any one of (m) to (v), and encoding a polypeptide having acetyl-CoA carboxylase activity.

3. The isolated polynucleotide of claim 1 or 2, wherein said polynucleotide encodes amino acid sequence which is identified by SEQ ID NO: 3 or has identity of 56.3 % or more with SEQ ID NO: 3.

4. The isolated polynucleotide of any one of claims 1 to 3, wherein said polynucleotide is derived from a strain of *P. rhodozyma* or *Xanthophylomyces dendrorhous*.

5. A method for making a recombinant vector comprising inserting the polynucleotide of any one of claims 1 to 4 into a vector.

6. A recombinant vector containing the polynucleotide of any one of claims 1 to 4 or produced by the method of claim 5.

7. The vector of claim 6 in which the polynucleotide of any one of claims 1 to 4 is operatively linked to expression control sequences allowing expression in prokaryotic or eukaryotic cells.

8. A method of making a recombinant organism comprising introducing the vector of claim 6 or 7 into a host organism.

9. The method of claim 8, wherein said host organism is selected from *E. coli*, baculovirus, or *S. cerevisiae*.

10. The recombinant organism containing the vector of claim 6 or 7, or produced by the method of claim 8 or 9.

11. A process for producing a polypeptide having acetyl-CoA carboxylase activity comprising culturing the recombinant organism of claim 10 and recovering the polypeptide from the culture of said recombinant organism.

12. A polypeptide obtainable by the process of claim 11.

13. An antibody that binds specifically to the polypeptide of claim 12.

14. An antisense polynucleotide against the polynucleotide of any one of claims 1 to 4.

15. A method for making a recombinant vector comprising inserting the polynucleotide of claim 14 into a vector.

16. A recombinant vector containing the polynucleotide of claim 14 or produced by the method of claim 15.

17. The vector of claim 16 in which the polynucleotide of claim 14 is operatively linked to expression control sequences allowing expression in prokaryotic or eukaryotic cells.

18. A method of making a recombinant organism comprising introducing the vector of claim 16 or 17 into a host organism.

SEQUENCE LISTING<110>
Roche Vitamins AG
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19. The method of claim 18, wherein said host organism is belongs to a strain of *Phaffia rhodozyma* or *Xanthophylomyces dendrorhous*.

20. The recombinant organism containing the vector of claim 16 or 17, or produced by the method of claim 18 or 19.

21. The recombinant organism of claim 20, wherein said organism is characterized in that whose gene expression of acetyl-CoA carboxylase is reduced compared to the host organism, thereby is capable of producing carotenoids in an enhanced level relative to a host organism.

22. The recombinant organism according to claim 21, wherein the gene expression of acetyl-CoA carboxylase is reduced by means of the technique selected from antisense technology, site-directed mutagenesis, error prone PCR, or chemical mutagenesis.

23. A process for producing carotenoids, which comprises cultivating the recombinant organism of claim 21.

24. The process of claim 23, wherein said carotenoids are selected one or more from astaxanthin, β-carotene, lycopene, zeaxanthin, canthaxanthin.

25. The process according to claim 23, wherein the gene expression of acetyl-CoA carboxylase is reduced in the recombinant organism of claim 21 by means of the technique selected from antisense technology, site-directed mutagenesis, error prone PCR, or chemical mutagenesis.

26. A process for the production of a carotenoid by culturing a microorganism under suitable conditions and, optionally, recovering the resulting carotenoid, wherein the microorganism is characterized in that its gene expression of acetyl-CoA carboxylase is reduced, e.g. by means of the technique selected from antisense technology, site-directed mutagenesis, error prone PCR, or chemical mutagenesis.

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aac act gag ggt tct ttc ctt cat aag act atg aaa gcg ctt gcc gac      5373
Asn Thr Glu Gly Ser Phe Leu His Lys Thr Met Lys Ala Leu Ala Asp
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gga gtg  ggt aag gag aac tct  tcc gat gtt cga ttc  ttt atc cgg      6579
Gly Val  Gly Lys Glu Asn Ser  Ser Asp Val Arg Phe  Phe Ile Arg
    1310                  1315                  1320
```

```
gtc  acc act tct tac tac  gga gag act gga ggt  gga cac ag          5608
Val  Thr Thr Ser Tyr Tyr  Gly Glu Thr Gly Gly  Gly His Arg
1030                 1035                 1040

gtttgtcctc tcccatgtgt ttctagttca tagctctctg ctgactctga tccgattttc  5668

aacag a aac cct  tcg gtt gat gtt ctg  act gag atc tca aac  tct      5713
       Asn Pro  Ser Val Asp Val Leu  Thr Glu Ile Ser Asn  Ser
           1045                 1050                 1055

cga ttc acc gtc  tac gat gtc ctg tcc  tcc ttc ttc aag cac  gat      5758
Arg Phe Thr Val  Tyr Asp Val Leu Ser  Ser Phe Phe Lys His  Asp
           1060                 1065                 1070

gat cct tgg att  gtt ctt gct agt ttg  acc gtc tac gtt ctt  cga      5803
Asp Pro Trp Ile  Val Leu Ala Ser Leu  Thr Val Tyr Val Leu  Arg
           1075                 1080                 1085

gc  gtaagtgatc gttcttctcc tcttgcccaa acaatgactg acagttctat         5855
Ala

ctattccatc tgcag t tac cga gag  tac agt att ctt gat  atg caa cat    5904
                  Tyr Arg Glu  Tyr Ser Ile Leu Asp  Met Gln His
                       1090                 1095

gag caa  ggt cag gat ggc gct  gct gga gtc atc act  tgg cga ttc      5949
Glu Gln  Gly Gln Asp Gly Ala  Ala Gly Val Ile Thr  Trp Arg Phe
    1100                 1105                 1110

aag ctc  aac cag ccc atc gct  gag tct tct act ccc  cga gtt gac      5994
Lys Leu  Asn Gln Pro Ile Ala  Glu Ser Ser Thr Pro  Arg Val Asp
    1115                 1120                 1125

tcg aat  cga gac gtt tac cga  gtc ggt tcg ctt tct  gat ttg acc      6039
Ser Asn  Arg Asp Val Tyr Arg  Val Gly Ser Leu Ser  Asp Leu Thr
    1130                 1135                 1140

tac aag  atc aag cag agt cag  acc gag ccc ctc cga  gct ggt gtc      6084
Tyr Lys  Ile Lys Gln Ser Gln  Thr Glu Pro Leu Arg  Ala Gly Val
    1145                 1150                 1155
```

```
gct ttg  gtt cga cct gga cgg  gtc cag gga tcg atg  aag gct gcc      6624
Ala Leu  Val Arg Pro Gly Arg  Val Gln Gly Ser Met  Lys Ala Ala
    1325                 1330                 1335

gag tat  ctc atc tcc gag tgc  gat cga ctg ctc act  gat atc ctg     6669
Glu Tyr  Leu Ile Ser Glu Cys  Asp Arg Leu Leu Thr  Asp Ile Leu
    1340                 1345                 1350

gac gcc  ttg gag gtt gtt gga  gcc gag act cga aac  gcc gat tgc     6714
Asp Ala  Leu Glu Val Val Gly  Ala Glu Thr Arg Asn  Ala Asp Cys
    1355                 1360                 1365

aac cat  gtt gga att aac ttc  atc tat aac gtt ctt  gtc gac ttc     6759
Asn His  Val Gly Ile Asn Phe  Ile Tyr Asn Val Leu  Val Asp Phe
    1370                 1375                 1380

gac gac  gtc cag gag gcc ctt  gcc ggg ttc att gag  agg cac gga     6804
Asp Asp  Val Gln Glu Ala Leu  Ala Gly Phe Ile Glu  Arg His Gly
    1385                 1390                 1395

aag agg  ctt tgg cga ctt cga  gtg acc g gtaagtgttc tctcggcatt     6852
Lys Arg  Leu Trp Arg Leu Arg  Val Thr
    1400                 1405

gaattcagca atgagctgtg actaacgggt ttcttcggta tattag ct  tct gaa    6906
                                                    Ala Ser Glu
                                                          1410

atc cga atg gtt ctt  gag gac gac gag ggt  aac gtc acc ccc atc     6951
Ile Arg Met Val Leu  Glu Asp Asp Glu Gly  Asn Val Thr Pro Ile
                1415                 1420                 1425
cga tgc tgc att gag  aac gtt tct g gtaagcagtc caaaataact         6996
Arg Cys Cys Ile Glu  Asn Val Ser
                1430

gataatccta ttcagtctag acattgtaac tgatgcattt ctcgttctta g gt  ttc  7052
                                                        Gly Phe
                                                            1435

gtc gtg aag tac cac  gcc tac cag gag gtt  gag acc gag aag ggt     7097
Val Val Lys Tyr His  Ala Tyr Gln Glu Val  Glu Thr Glu Lys Gly
                1440                 1445                 1450
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```
act acc atc ttg aag  tca atc gga gac ctt  gga cct ctt cac ctt      7142
Thr Thr Ile Leu Lys  Ser Ile Gly Asp Leu  Gly Pro Leu His Leu
                1455                1460                1465

cag cct gtc aac cat  gct tac cag acc aag  aac agt ctt cag ccc      7187
Gln Pro Val Asn His  Ala Tyr Gln Thr Lys  Asn Ser Leu Gln Pro
                1470                1475                1480

cga cga tac cag gct  cac ttg gtt gga acg  act tac gtc t            7227
Arg Arg Tyr Gln Ala  His Leu Val Gly Thr  Thr Tyr Val
                1485                1490

gttagtcaca tttcatgctc tggttttctg accgtcactg gttattgacg ttctgtttgg  7287

cgtcacag ac  gac  tac ccc gat ctc ttc  gtt cag agt ttg cgc  aag     7333
         Tyr Asp  Tyr Pro Asp Leu Phe  Val Gln Ser Leu Arg  Lys
            1495                1500                1505

gtt tgg gct gag  gct gct gct aag att  cct cac ctc cgg gtg  cct     7378
Val Trp Ala Glu  Ala Ala Ala Lys Ile  Pro His Leu Arg Val  Pro
            1510                1515                1520

agc gag cct ctt  acc gct acc gag ttg  gtt ctc gat gag aac  aac     7423
Ser Glu Pro Leu  Thr Ala Thr Glu Leu  Val Leu Asp Glu Asn  Asn
            1525                1530                1535

gag ctt cag gag  gtc gag cga cct ccg  ggt tcc aac tcg tgt  ggt     7468
Glu Leu Gln Glu  Val Glu Arg Pro Pro  Gly Ser Asn Ser Cys  Gly
            1540                1545                1550

atg gtc gcc tgg  atc ttc act atg ctc  act ccc gag tat ccc  aag     7513
Met Val Ala Trp  Ile Phe Thr Met Leu  Thr Pro Glu Tyr Pro  Lys
            1555                1560                1565

ggt cga cga gta  gtt gcc att gcc aac  gat atc acc ttc aag  att     7558
Gly Arg Arg Val  Val Ala Ile Ala Asn  Asp Ile Thr Phe Lys  Ile
            1570                1575                1580

gga tcc ttt ggt  cct aag gaa gac gat  tac ttc ttc aag gct  act     7603
Gly Ser Phe Gly  Pro Lys Glu Asp Asp  Tyr Phe Phe Lys Ala  Thr
            1585                1590                1595
```

```
gaa att gcc aag  aag ctg ggc ctt cct  cga att tac ctc tct  gcc      7648
Glu Ile Ala Lys  Lys Leu Gly Leu Pro  Arg Ile Tyr Leu Ser  Ala
            1600                 1605                 1610

aac agt gga gct  aga ctc ggt atc gcg  gag gag ctc ttg cac  atc      7693
Asn Ser Gly Ala  Arg Leu Gly Ile Ala  Glu Glu Leu Leu His  Ile
            1615                 1620                 1625

ttc aag gcg gcc  ttc gtt gac ccc gca  aag cct tcc atg ggt  att      7738
Phe Lys Ala Ala  Phe Val Asp Pro Ala  Lys Pro Ser Met Gly  Ile
            1630                 1635                 1640

aag tat cta tac  ttg acc cct gaa act  tta tcc act ctt gcc  aag      7783
Lys Tyr Leu Tyr  Leu Thr Pro Glu Thr  Leu Ser Thr Leu Ala  Lys
            1645                 1650                 1655

aag gga tcc agc  gtc acc act gag gag  atc gag gat gac ggc  gag      7828
Lys Gly Ser Ser  Val Thr Thr Glu Glu  Ile Glu Asp Asp Gly  Glu
            1660                 1665                 1670

cga cga cac aag  atc acc gcc atc atc  ggt ctt gca gag ggt  ttg      7873
Arg Arg His Lys  Ile Thr Ala Ile Ile  Gly Leu Ala Glu Gly  Leu
            1675                 1680                 1685

gga gtt gag tct  ctt cga gga tcc ggt  ctt att gct gga gcc  acc      7918
Gly Val Glu Ser  Leu Arg Gly Ser Gly  Leu Ile Ala Gly Ala  Thr
            1690                 1695                 1700

act cga gct tac  gag gag gga atc ttc  acc atc tct ctc gtt  act      7963
Thr Arg Ala Tyr  Glu Glu Gly Ile Phe  Thr Ile Ser Leu Val  Thr
            1705                 1710                 1715
gcc cga tcg gtc  ggt atc gga gct tac  ttg gtt cga ttg ggt  cag      8008
Ala Arg Ser Val  Gly Ile Gly Ala Tyr  Leu Val Arg Leu Gly  Gln
            1720                 1725                 1730

cga gct att cag  gtt gaa ggc aac cct  atg atc ctt act gga  gct      8053
Arg Ala Ile Gln  Val Glu Gly Asn Pro  Met Ile Leu Thr Gly  Ala
            1735                 1740                 1745

cag tct ctc aac  aag gtg ctt gga cga  gag gtt tac act tcc  aac      8098
Gln Ser Leu Asn  Lys Val Leu Gly Arg  Glu Val Tyr Thr Ser  Asn
            1750                 1755                 1760
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ctt cag ctt gga  gga acc cag att atg  gcc cga aac ggt acc  acg      8143
Leu Gln Leu Gly  Gly Thr Gln Ile Met  Ala Arg Asn Gly Thr  Thr
            1765                 1770                 1775

cat ctc gtc gct  gaa tct gat ctc gat  ggt gct ctc aag gtc  atc      8188
His Leu Val Ala  Glu Ser Asp Leu Asp  Gly Ala Leu Lys Val  Ile
            1780                 1785                 1790

cag tgg ctc tcg  tat gtg ccc gag cga  aag ggc aag gcc att  cct      8233
Gln Trp Leu Ser  Tyr Val Pro Glu Arg  Lys Gly Lys Ala Ile  Pro
            1795                 1800                 1805

atc tgg cct tcc  gag gac cct tgg gac  cga act gtg acc tac  gag      8278
Ile Trp Pro Ser  Glu Asp Pro Trp Asp  Arg Thr Val Thr Tyr  Glu
            1810                 1815                 1820

cct ccc cga ggt  cct tac gat cct cga  tgg ttg ctt gaa gga  aag      8323
Pro Pro Arg Gly  Pro Tyr Asp Pro Arg  Trp Leu Leu Glu Gly  Lys
            1825                 1830                 1835

ccg gat gaa ggc  ttg act ggt ctt ttc  gac aag gga tct ttc  atg      8368
Pro Asp Glu Gly  Leu Thr Gly Leu Phe  Asp Lys Gly Ser Phe  Met
            1840                 1845                 1850

gag acc ctt gga  gat tgg gcc aag act  atc gtc acc ggt cga  gcc      8413
Glu Thr Leu Gly  Asp Trp Ala Lys Thr  Ile Val Thr Gly Arg  Ala
            1855                 1860                 1865

cga ctg gga ggc  att cct atg ggt gtt  att gct gtc gaa acc  agg      8458
Arg Leu Gly Gly  Ile Pro Met Gly Val  Ile Ala Val Glu Thr  Arg
            1870                 1875                 1880
acg acc gag aag  atc atc gct gcc gat  cct gcc aac cct gca  gct      8503
Thr Thr Glu Lys  Ile Ile Ala Ala Asp  Pro Ala Asn Pro Ala  Ala
            1885                 1890                 1895

ttc gag caa aag  att atg gag gct ggt  cag gtt tgg aac ccc  aac      8548
Phe Glu Gln Lys  Ile Met Glu Ala Gly  Gln Val Trp Asn Pro  Asn
            1900                 1905                 1910

gct gct tac aag  acc gct caa tcc atc  ttt gat atc aac aag  gag      8593
Ala Ala Tyr Lys  Thr Ala Gln Ser Ile  Phe Asp Ile Asn Lys  Glu
            1915                 1920                 1925
```

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ggt ctt cct ttg  atg atc ctt gcc aac  atc cga ggt ttc tct  gga      8638
Gly Leu Pro Leu  Met Ile Leu Ala Asn  Ile Arg Gly Phe Ser  Gly
            1930                 1935                 1940

gga cag ggt gat  atg ttt gac gct atc  ctc aag cag ggt tct  aag      8683
Gly Gln Gly Asp  Met Phe Asp Ala Ile  Leu Lys Gln Gly Ser  Lys
            1945                 1950                 1955

atc gtt gac ggt  ctc tcg aac ttc aag  cag cca gtg ttc gtc  tat      8728
Ile Val Asp Gly  Leu Ser Asn Phe Lys  Gln Pro Val Phe Val  Tyr
            1960                 1965                 1970

gtt gtc ccc aac  gga gag ctt cgt gga  gga gct tgg gtc gtg  ttg      8773
Val Val Pro Asn  Gly Glu Leu Arg Gly  Gly Ala Trp Val Val  Leu
            1975                 1980                 1985

gat cct act atc  aac ctt gcc aag atg  gag atg tac gct gat  gaa      8818
Asp Pro Thr Ile  Asn Leu Ala Lys Met  Glu Met Tyr Ala Asp  Glu
            1990                 1995                 2000

acc gct cga gga  gga att ctc gag ccg  gaa ggt atc gtt gag  atc      8863
Thr Ala Arg Gly  Gly Ile Leu Glu Pro  Glu Gly Ile Val Glu  Ile
            2005                 2010                 2015

aag ttc cga cga  gac aag gtc atc gct  acc atg gag cga ttg  gac      8908
Lys Phe Arg Arg  Asp Lys Val Ile Ala  Thr Met Glu Arg Leu  Asp
            2020                 2025                 2030

gag acc tat gcc  tct ctc aaa gct gcc  tcg aac gac tca acc  aag      8953
Glu Thr Tyr Ala  Ser Leu Lys Ala Ala  Ser Asn Asp Ser Thr  Lys
            2035                 2040                 2045
tct gcg gag gag  cga gct aag agt gct  gag cta ctc aag gca  aga      8998
Ser Ala Glu Glu  Arg Ala Lys Ser Ala  Glu Leu Leu Lys Ala  Arg
            2050                 2055                 2060

gag act cta ctt  caa ccg acg tac ttg  cag att gca cac ctt  tac      9043
Glu Thr Leu Leu  Gln Pro Thr Tyr Leu  Gln Ile Ala His Leu  Tyr
            2065                 2070                 2075

gct gat ctc cat  gat cgt gtc gga cga  atg gag gcc aag ggt  tgc      9088
Ala Asp Leu His  Asp Arg Val Gly Arg  Met Glu Ala Lys Gly  Cys
            2080                 2085                 2090
```

```
gcg aag cga gct  gtc tgg gct gag gct  cga cga ttc ttc tac  tgg      9133
Ala Lys Arg Ala  Val Trp Ala Glu Ala  Arg Arg Phe Phe Tyr  Trp
             2095                 2100                 2105

cga ctt cga cga  cgt ctc aac gat gag  gtgagccgtc ccattcactc        9180
Arg Leu Arg Arg  Arg Leu Asn Asp Glu
             2110                 2115

tttcgttgca aggttcagta gtactaaccg cttctttctt tatctatcag cac atc     9236
                                                        His Ile

ctg tct aag  ttc gct gct gcc aac  ccg gat ctt act ctc  gag gag      9281
Leu Ser Lys  Phe Ala Ala Ala Asn  Pro Asp Leu Thr Leu  Glu Glu
        2120                 2125                 2130

cga caa aac  att ctc gac tct gtc  gtc cag act gac ctc  act gat      9326
Arg Gln Asn  Ile Leu Asp Ser Val  Val Gln Thr Asp Leu  Thr Asp
        2135                 2140                 2145

gac cga gcc  acc gct gaa tgg att  gag cag tct gca gaa  gag att      9371
Asp Arg Ala  Thr Ala Glu Trp Ile  Glu Gln Ser Ala Glu  Glu Ile
        2150                 2155                 2160

gct gct gcc  gtt gcc gaa gtc cga  tcc acc tac gtg tcg  aat aag      9416
Ala Ala Ala  Val Ala Glu Val Arg  Ser Thr Tyr Val Ser  Asn Lys
        2165                 2170                 2175

att atc agc  ttc gcc gag acg gag  cga gct gga gcg ttg  cag ggc      9461
Ile Ile Ser  Phe Ala Glu Thr Glu  Arg Ala Gly Ala Leu  Gln Gly
        2180                 2185                 2190
ttg gtc gct  gtc ttg agc act ttg  aat gcg gaa gac aag  aag gcc      9506
Leu Val Ala  Val Leu Ser Thr Leu  Asn Ala Glu Asp Lys  Lys Ala
        2195                 2200                 2205

ctt gtt tct  agc ctt ggt ctc taa attttaattt tttttgtcga tgctattctt   9560
Leu Val Ser  Ser Leu Gly Leu
        2210

cctatctttta gtctttgatt aacttttgaa tatccttcat agatctttcc ttgcatacat   9620

tgatattatt tcctcacccg tttttatgta cttccatacg agtttccatt ttttttctgct   9680
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tttatatttc gactacacgt cgactgttca cctgcctctc ttttgttctt tctgttctgt 9740

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1 5 10 15

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Leu Glu Asn Ala Pro Pro Ser Ser Val Thr Asp Phe Val Arg Ser Gln
20 25 30

gat ggt cac acg gtc atc acc aaa gtc ctc att gcc aac aac gga atc 144
Asp Gly His Thr Val Ile Thr Lys Val Leu Ile Ala Asn Asn Gly Ile
35 40 45

gct gct gta aaa gag atc cga tca gtt cgt aaa tgg gct tac gag acg 192
Ala Ala Val Lys Glu Ile Arg Ser Val Arg Lys Trp Ala Tyr Glu Thr
50 55 60

ttt gga gat gag cga gcc atc gaa ttt acg gta atg gcc act cca gaa 240
Phe Gly Asp Glu Arg Ala Ile Glu Phe Thr Val Met Ala Thr Pro Glu
65 70 75 80

gat ttg aag gtg aac tgc gac tat att cga atg gct gat cga gtc gtc 288
Asp Leu Lys Val Asn Cys Asp Tyr Ile Arg Met Ala Asp Arg Val Val
85 90 95

gaa gtt cct gga gga act aac aac aac aat cac tct aac gtc gac ctc 336
Glu Val Pro Gly Gly Thr Asn Asn Asn Asn His Ser Asn Val Asp Leu
100 105 110

atc gtt gac att gcc gag cga ttc aat ata cat gct gtt tgg gct gga 384
Ile Val Asp Ile Ala Glu Arg Phe Asn Ile His Ala Val Trp Ala Gly
115 120 125

tgg ggt cac gct tcg gaa aac ccc aga ctt ccc gag tct ctc gcc gcc 432
Trp Gly His Ala Ser Glu Asn Pro Arg Leu Pro Glu Ser Leu Ala Ala
130 135 140

tca aag aac aag atc gtc ttc att ggt cct ccc gga tcc gct atg cga 480
Ser Lys Asn Lys Ile Val Phe Ile Gly Pro Pro Gly Ser Ala Met Arg
145 150 155 160

tcc ctt gga gac aag att tct tcg acc atc gtt gcc cag tct gcc cag 528
Ser Leu Gly Asp Lys Ile Ser Ser Thr Ile Val Ala Gln Ser Ala Gln

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                    165                 170                 175

gtg ccg tgt atg gcc tgg tct gga tca ggc atc act gat aca gag ctc      576
Val Pro Cys Met Ala Trp Ser Gly Ser Gly Ile Thr Asp Thr Glu Leu
            180                 185                 190

agc cct cag ggc ttc gtg act gtg ccc gat ggg cca tat cag gct gct      624
Ser Pro Gln Gly Phe Val Thr Val Pro Asp Gly Pro Tyr Gln Ala Ala
        195                 200                 205

tgt gta aag acg gtg gag gat ggt ttg gtg cga gcc gag aag atc ggt      672
Cys Val Lys Thr Val Glu Asp Gly Leu Val Arg Ala Glu Lys Ile Gly
    210                 215                 220

ttg cca gtt atg atc aag gcc tct gag gga gga gga gga aag ggt atc      720
Leu Pro Val Met Ile Lys Ala Ser Glu Gly Gly Gly Gly Lys Gly Ile
225                 230                 235                 240

cga atg gtt cac agc atg gac aca ttc aag aac tcc tac aac tcc gtc      768
Arg Met Val His Ser Met Asp Thr Phe Lys Asn Ser Tyr Asn Ser Val
                245                 250                 255

gct tcc gag gtg cca gga tct ccg att ttc atc atg gcc ttg gct gga      816
Ala Ser Glu Val Pro Gly Ser Pro Ile Phe Ile Met Ala Leu Ala Gly
            260                 265                 270

tct gct cga cat ttg gag gtc cag ctc ctt gct gat cag tac gga aac      864
Ser Ala Arg His Leu Glu Val Gln Leu Leu Ala Asp Gln Tyr Gly Asn
        275                 280                 285

gct atc tct ttg ttc ggt cga gat tgc tct gtt cag cga cga cat cag      912
Ala Ile Ser Leu Phe Gly Arg Asp Cys Ser Val Gln Arg Arg His Gln
    290                 295                 300
aag atc att gag gag gct ccc gtc acg atc gct cgt cca gag aga ttc      960
Lys Ile Ile Glu Glu Ala Pro Val Thr Ile Ala Arg Pro Glu Arg Phe
305                 310                 315                 320

gaa gag atg gag aag gct gct gtc agg ttg gcc aag tta gta gga tat     1008
Glu Glu Met Glu Lys Ala Ala Val Arg Leu Ala Lys Leu Val Gly Tyr
                325                 330                 335

gtt agt gcc ggt acc gtc gaa tac ctc tac tct cac gcc gac gac tca     1056
Val Ser Ala Gly Thr Val Glu Tyr Leu Tyr Ser His Ala Asp Asp Ser
            340                 345                 350
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gat ttc gag cag aac gcc att acc acc gct tgg ttg gat ggg ttg atc      1632
Asp Phe Glu Gln Asn Ala Ile Thr Thr Ala Trp Leu Asp Gly Leu Ile
    530                 535                 540

act aac aag ctt aca tct gag agg cct gat cca tca ctg gcc gtt att      1680
Thr Asn Lys Leu Thr Ser Glu Arg Pro Asp Pro Ser Leu Ala Val Ile
545                 550                 555                 560

tgt ggt gca att gtg aaa gct cac gtg gct tct gag aac tgt tgg gcc      1728
Cys Gly Ala Ile Val Lys Ala His Val Ala Ser Glu Asn Cys Trp Ala
                565                 570                 575

gaa tac cga cga gta ttg gac aag gga cag gtt ccc tcc aag gac act      1776
Glu Tyr Arg Arg Val Leu Asp Lys Gly Gln Val Pro Ser Lys Asp Thr
            580                 585                 590

ctc aag aca gtg ttc act ctt gat ttc atc tat gag ggt gtt cgg tac      1824
Leu Lys Thr Val Phe Thr Leu Asp Phe Ile Tyr Glu Gly Val Arg Tyr
        595                 600                 605

aat ttc acc gct gct cga gcc tcc ctc aac act tac cga ttg tat cta      1872
Asn Phe Thr Ala Ala Arg Ala Ser Leu Asn Thr Tyr Arg Leu Tyr Leu
    610                 615                 620

aac gga gga aag acc gtg gtg tcc atc cga cct ttg gcc gat ggt gga      1920
Asn Gly Gly Lys Thr Val Val Ser Ile Arg Pro Leu Ala Asp Gly Gly
625                 630                 635                 640

atg ctc gtt ctt ctc gat ggc cga tcc cac act ctc tac tgg agg gag      1968
Met Leu Val Leu Leu Asp Gly Arg Ser His Thr Leu Tyr Trp Arg Glu
                645                 650                 655

gaa gtc ggt acc ctc cga att cag gta gac gca aag act tgc ctg att      2016
Glu Val Gly Thr Leu Arg Ile Gln Val Asp Ala Lys Thr Cys Leu Ile
            660                 665                 670

gag cag gag aac gac ccc act cag ctc cga tca ccc tcg cct gga aag      2064
Glu Gln Glu Asn Asp Pro Thr Gln Leu Arg Ser Pro Ser Pro Gly Lys
        675                 680                 685

atc atc cgg ttt ttg gtc gaa agc gga gat cac atc tcc tcc gga gat      2112
Ile Ile Arg Phe Leu Val Glu Ser Gly Asp His Ile Ser Ser Gly Asp
    690                 695                 700
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ttc ttc ttc ctc gaa ctc aac cct cga ctt caa gtc gag cac cct act   1104
Phe Phe Phe Leu Glu Leu Asn Pro Arg Leu Gln Val Glu His Pro Thr
        355                 360                 365

acc gag atg gtc tcg ggt gtc aac ctt ccc gct gct cag ctt cag att   1152
Thr Glu Met Val Ser Gly Val Asn Leu Pro Ala Ala Gln Leu Gln Ile
    370                 375                 380

gct atg ggt atc cct ctt tct cga att cgg gat att cga gtc ctc tac   1200
Ala Met Gly Ile Pro Leu Ser Arg Ile Arg Asp Ile Arg Val Leu Tyr
385                 390                 395                 400

ggt ctc gat ccc cac act gtt tcc gag atc gac ttc gac agc agc aga   1248
Gly Leu Asp Pro His Thr Val Ser Glu Ile Asp Phe Asp Ser Ser Arg
                405                 410                 415

gcg gag tct gtc cag act cag agg aag cct agg ccc aag ggt cac gtc   1296
Ala Glu Ser Val Gln Thr Gln Arg Lys Pro Arg Pro Lys Gly His Val
            420                 425                 430

att gcc tgt cga atc acg agt gaa aac ccc gat gag ggg ttc aag ccg   1344
Ile Ala Cys Arg Ile Thr Ser Glu Asn Pro Asp Glu Gly Phe Lys Pro
        435                 440                 445

tct gcc gga gat atc caa gag ttg aac ttc aga agt aat act aac gtc   1392
Ser Ala Gly Asp Ile Gln Glu Leu Asn Phe Arg Ser Asn Thr Asn Val
    450                 455                 460

tgg gga tac ttc tct gtt gga gct act gga gga att cat agt ttc gcc   1440
Trp Gly Tyr Phe Ser Val Gly Ala Thr Gly Gly Ile His Ser Phe Ala
465                 470                 475                 480
gat tct caa ttc ggt cac gtg ttt gct tat ggc tcc gac cga acg act   1488
Asp Ser Gln Phe Gly His Val Phe Ala Tyr Gly Ser Asp Arg Thr Thr
                485                 490                 495

gcc aga aag aat atg gtt atc gcc ttg aaa gag ctt tcc att cga gga   1536
Ala Arg Lys Asn Met Val Ile Ala Leu Lys Glu Leu Ser Ile Arg Gly
            500                 505                 510

gac ttc cga acc act gtc gag tat ctt atc act ctt ctt gag acg agc   1584
Asp Phe Arg Thr Thr Val Glu Tyr Leu Ile Thr Leu Leu Glu Thr Ser
        515                 520                 525
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atc tat gct gag gtt gag gtc atg aag atg atc ttg ccc ttg att gcc     2160
Ile Tyr Ala Glu Val Glu Val Met Lys Met Ile Leu Pro Leu Ile Ala
705                 710                 715                 720

cag gag tcc ggt cac gtt cag ttt gtc aag caa gcc ggt gtg acc gtc     2208
Gln Glu Ser Gly His Val Gln Phe Val Lys Gln Ala Gly Val Thr Val
                725                 730                 735

gat cct gga gcg att att ggg atc ttg agt ctt gat gac cct acg cga     2256
Asp Pro Gly Ala Ile Ile Gly Ile Leu Ser Leu Asp Asp Pro Thr Arg
            740                 745                 750

gtg aag aag gcg aag ccc ttc gag ggt ctc ctg cct gtg act ggt ctc     2304
Val Lys Lys Ala Lys Pro Phe Glu Gly Leu Leu Pro Val Thr Gly Leu
        755                 760                 765

cct aac ctg ccc ggt aac aga cct cac cag cgg cta cag ttc cag ctt     2352
Pro Asn Leu Pro Gly Asn Arg Pro His Gln Arg Leu Gln Phe Gln Leu
    770                 775                 780

gag tcg ata tac tcg gtc ttg gat gga tac gag agt gac tcc act gca     2400
Glu Ser Ile Tyr Ser Val Leu Asp Gly Tyr Glu Ser Asp Ser Thr Ala
785                 790                 795                 800

aca atc ctc cga tca ttc tct gaa aac ctt tat gat cct gat ctt gct     2448
Thr Ile Leu Arg Ser Phe Ser Glu Asn Leu Tyr Asp Pro Asp Leu Ala
                805                 810                 815

ttc gga gag gct tta tcc atc att tcc gtc ctt tct ggg aga atg cct     2496
Phe Gly Glu Ala Leu Ser Ile Ile Ser Val Leu Ser Gly Arg Met Pro
            820                 825                 830

gcc gat ctt gag gag agc att cga gag gtc atc agc gaa gct cag tcg     2544
Ala Asp Leu Glu Glu Ser Ile Arg Glu Val Ile Ser Glu Ala Gln Ser
        835                 840                 845

aag cct cac gcc gag ttc cct gga tca aag atc ctc aaa gtc gtc gag     2592
Lys Pro His Ala Glu Phe Pro Gly Ser Lys Ile Leu Lys Val Val Glu
    850                 855                 860

cgg tac atc gat aat ttg cga cct cag gag agg gct atg gtc cga act     2640
Arg Tyr Ile Asp Asn Leu Arg Pro Gln Glu Arg Ala Met Val Arg Thr
865                 870                 875                 880
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cag atc gaa ccc atc gtt ggt att gct gag aag aac gtt ggc ggt cct      2688
Gln Ile Glu Pro Ile Val Gly Ile Ala Glu Lys Asn Val Gly Gly Pro
                885                 890                 895

aag ggt tac gcc tct tac gtc tta gct acc atc ctt caa aag ttc ttg      2736
Lys Gly Tyr Ala Ser Tyr Val Leu Ala Thr Ile Leu Gln Lys Phe Leu
            900                 905                 910

gcc gtt gag gcc gtt ttt gct act ggt agt gaa gag gcc att gtt ctc      2784
Ala Val Glu Ala Val Phe Ala Thr Gly Ser Glu Glu Ala Ile Val Leu
        915                 920                 925

caa ctt cga gat gaa aac cga gaa tct ttg aac gac gtc ctt ggt ctc      2832
Gln Leu Arg Asp Glu Asn Arg Glu Ser Leu Asn Asp Val Leu Gly Leu
    930                 935                 940

gtc ctg gct cac tcg cgt ctc agc gct cga tcc aag ctt gtt ctc tcc      2880
Val Leu Ala His Ser Arg Leu Ser Ala Arg Ser Lys Leu Val Leu Ser
945                 950                 955                 960

gtc ttt gat ctg atc aag tct atg cag ctc ctc aac aac act gag ggt      2928
Val Phe Asp Leu Ile Lys Ser Met Gln Leu Leu Asn Asn Thr Glu Gly
                965                 970                 975

tct ttc ctt cat aag act atg aaa gcg ctt gcc gac atg ccc acc aag      2976
Ser Phe Leu His Lys Thr Met Lys Ala Leu Ala Asp Met Pro Thr Lys
            980                 985                 990

gct cct ttg gcc agc aag gtg tct  ttg aag gct cgg gaa  att ctt atc    3024
Ala Pro Leu Ala Ser Lys Val Ser  Leu Lys Ala Arg Glu  Ile Leu Ile
        995                 1000                1005
tct tgc  tct ctt ccc tct tac  gag gag agg ttg ttc  cag atg gaa       3069
Ser Cys  Ser Leu Pro Ser Tyr  Glu Glu Arg Leu Phe  Gln Met Glu
    1010                1015                1020

aag atc  ctt aac tct tct gtc  acc act tct tac tac  gga gag act       3114
Lys Ile  Leu Asn Ser Ser Val  Thr Thr Ser Tyr Tyr  Gly Glu Thr
    1025                1030                1035

gga ggt  gga cac aga aac cct  tcg gtt gat gtt ctg  act gag atc       3159
Gly Gly  Gly His Arg Asn Pro  Ser Val Asp Val Leu  Thr Glu Ile
    1040                1045                1050
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tca aac  tct cga ttc acc gtc  tac gat gtc ctg tcc  tcc ttc ttc      3204
Ser Asn  Ser Arg Phe Thr Val  Tyr Asp Val Leu Ser  Ser Phe Phe
    1055                 1060                 1065

aag cac  gat gat cct tgg att  gtt ctt gct agt ttg  acc gtc tac      3249
Lys His  Asp Asp Pro Trp Ile  Val Leu Ala Ser Leu  Thr Val Tyr
    1070                 1075                 1080

gtt ctt  cga gct tac cga gag  tac agt att ctt gat  atg caa cat      3294
Val Leu  Arg Ala Tyr Arg Glu  Tyr Ser Ile Leu Asp  Met Gln His
    1085                 1090                 1095

gag caa  ggt cag gat ggc gct  gct gga gtc atc act  tgg cga ttc      3339
Glu Gln  Gly Gln Asp Gly Ala  Ala Gly Val Ile Thr  Trp Arg Phe
    1100                 1105                 1110

aag ctc  aac cag ccc atc gct  gag tct tct act ccc  cga gtt gac      3384
Lys Leu  Asn Gln Pro Ile Ala  Glu Ser Ser Thr Pro  Arg Val Asp
    1115                 1120                 1125

tcg aat  cga gac gtt tac cga  gtc ggt tcg ctt tct  gat ttg acc      3429
Ser Asn  Arg Asp Val Tyr Arg  Val Gly Ser Leu Ser  Asp Leu Thr
    1130                 1135                 1140

tac aag  atc aag cag agt cag  acc gag ccc ctc cga  gct ggt gtc      3474
Tyr Lys  Ile Lys Gln Ser Gln  Thr Glu Pro Leu Arg  Ala Gly Val
    1145                 1150                 1155

atg acg  agc ttc aac aac ttg  aag gag gtt cag gac  gga ctc ttg      3519
Met Thr  Ser Phe Asn Asn Leu  Lys Glu Val Gln Asp  Gly Leu Leu
    1160                 1165                 1170
aat gtt  ctg tct ttc ttc cct  gct tac cat cat caa  gat ttc act      3564
Asn Val  Leu Ser Phe Phe Pro  Ala Tyr His His Gln  Asp Phe Thr
    1175                 1180                 1185

caa cga  cat ggt cag gac agt  gcc atg ccc aac gtt  ctc aac att      3609
Gln Arg  His Gly Gln Asp Ser  Ala Met Pro Asn Val  Leu Asn Ile
    1190                 1195                 1200

gct atc  cgg gct ttc gag gag  aag gac gac atg tct  gat ctt gat      3654
Ala Ile  Arg Ala Phe Glu Glu  Lys Asp Asp Met Ser  Asp Leu Asp
    1205                 1210                 1215
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tgg gcc  aag agt gtt gag tcg  ctg gta atg cag atg  tct gcc gag      3699
Trp Ala  Lys Ser Val Glu Ser  Leu Val Met Gln Met  Ser Ala Glu
    1220                 1225                 1230

atc cag  aag aag gga att cga  cga gtt acc ttc ttg  gtt tgc cga      3744
Ile Gln  Lys Lys Gly Ile Arg  Arg Val Thr Phe Leu  Val Cys Arg
    1235                 1240                 1245

aag ggc  gtt tac ccc tcc tac  ttc acc ttc aga caa  gag ggt gcc      3789
Lys Gly  Val Tyr Pro Ser Tyr  Phe Thr Phe Arg Gln  Glu Gly Ala
    1250                 1255                 1260

cag ggc  ccc tgg aga gag gag  gag aag att cga aac  atc gag cct      3834
Gln Gly  Pro Trp Arg Glu Glu  Glu Lys Ile Arg Asn  Ile Glu Pro
    1265                 1270                 1275

gct cta  gcc agt cag ctt gag  ctc aac cga ctc tcg  aat ttc aag      3879
Ala Leu  Ala Ser Gln Leu Glu  Leu Asn Arg Leu Ser  Asn Phe Lys
    1280                 1285                 1290

gtc acc  cct atc ttc gta gac  aac aga cag atc cac  atc tac aag      3924
Val Thr  Pro Ile Phe Val Asp  Asn Arg Gln Ile His  Ile Tyr Lys
    1295                 1300                 1305

gga gtg  ggt aag gag aac tct  tcc gat gtt cga ttc  ttt atc cgg      3969
Gly Val  Gly Lys Glu Asn Ser  Ser Asp Val Arg Phe  Phe Ile Arg
    1310                 1315                 1320

gct ttg  gtt cga cct gga cgg  gtc cag gga tcg atg  aag gct gcc      4014
Ala Leu  Val Arg Pro Gly Arg  Val Gln Gly Ser Met  Lys Ala Ala
    1325                 1330                 1335
gag tat  ctc atc tcc gag tgc  gat cga ctg ctc act  gat atc ctg      4059
Glu Tyr  Leu Ile Ser Glu Cys  Asp Arg Leu Leu Thr  Asp Ile Leu
    1340                 1345                 1350

gac gcc  ttg gag gtt gtt gga  gcc gag act cga aac  gcc gat tgc      4104
Asp Ala  Leu Glu Val Val Gly  Ala Glu Thr Arg Asn  Ala Asp Cys
    1355                 1360                 1365

aac cat  gtt gga att aac ttc  atc tat aac gtt ctt  gtc gac ttc      4149
Asn His  Val Gly Ile Asn Phe  Ile Tyr Asn Val Leu  Val Asp Phe
    1370                 1375                 1380
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gac gac  gtc cag gag gcc ctt  gcc ggg ttc att gag  agg cac gga   4194
Asp Asp  Val Gln Glu Ala Leu  Ala Gly Phe Ile Glu  Arg His Gly
    1385                 1390                 1395

aag agg  ctt tgg cga ctt cga  gtg acc gct tct gaa  atc cga atg   4239
Lys Arg  Leu Trp Arg Leu Arg  Val Thr Ala Ser Glu  Ile Arg Met
    1400                 1405                 1410

gtt ctt  gag gac gac gag ggt  aac gtc acc ccc atc  cga tgc tgc   4284
Val Leu  Glu Asp Asp Glu Gly  Asn Val Thr Pro Ile  Arg Cys Cys
    1415                 1420                 1425

att gag  aac gtt tct ggt ttc  gtc gtg aag tac cac  gcc tac cag   4329
Ile Glu  Asn Val Ser Gly Phe  Val Val Lys Tyr His  Ala Tyr Gln
    1430                 1435                 1440

gag gtt  gag acc gag aag ggt  act acc atc ttg aag  tca atc gga   4374
Glu Val  Glu Thr Glu Lys Gly  Thr Thr Ile Leu Lys  Ser Ile Gly
    1445                 1450                 1455

gac ctt  gga cct ctt cac ctt  cag cct gtc aac cat  gct tac cag   4419
Asp Leu  Gly Pro Leu His Leu  Gln Pro Val Asn His  Ala Tyr Gln
    1460                 1465                 1470

acc aag  aac agt ctt cag ccc  cga cga tac cag gct  cac ttg gtt   4464
Thr Lys  Asn Ser Leu Gln Pro  Arg Arg Tyr Gln Ala  His Leu Val
    1475                 1480                 1485

gga acg  act tac gtc tac gac  tac ccc gat ctc ttc  gtt cag agt   4509
Gly Thr  Thr Tyr Val Tyr Asp  Tyr Pro Asp Leu Phe  Val Gln Ser
    1490                 1495                 1500
ttg cgc  aag gtt tgg gct gag  gct gct gct aag att  cct cac ctc   4554
Leu Arg  Lys Val Trp Ala Glu  Ala Ala Ala Lys Ile  Pro His Leu
    1505                 1510                 1515

cgg gtg  cct agc gag cct ctt  acc gct acc gag ttg  gtt ctc gat   4599
Arg Val  Pro Ser Glu Pro Leu  Thr Ala Thr Glu Leu  Val Leu Asp
    1520                 1525                 1530

gag aac  aac gag ctt cag gag  gtc gag cga cct ccg  ggt tcc aac   4644
Glu Asn  Asn Glu Leu Gln Glu  Val Glu Arg Pro Pro  Gly Ser Asn
    1535                 1540                 1545
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tcg tgt  ggt atg gtc gcc tgg  atc ttc act atg ctc  act ccc gag      4689
Ser Cys  Gly Met Val Ala Trp  Ile Phe Thr Met Leu  Thr Pro Glu
    1550                 1555                 1560

tat ccc  aag ggt cga cga gta  gtt gcc att gcc aac  gat atc acc      4734
Tyr Pro  Lys Gly Arg Arg Val  Val Ala Ile Ala Asn  Asp Ile Thr
    1565                 1570                 1575

ttc aag  att gga tcc ttt ggt  cct aag gaa gac gat  tac ttc ttc      4779
Phe Lys  Ile Gly Ser Phe Gly  Pro Lys Glu Asp Asp  Tyr Phe Phe
    1580                 1585                 1590

aag gct  act gaa att gcc aag  aag ctg ggc ctt cct  cga att tac      4824
Lys Ala  Thr Glu Ile Ala Lys  Lys Leu Gly Leu Pro  Arg Ile Tyr
    1595                 1600                 1605

ctc tct  gcc aac agt gga gct  aga ctc ggt atc gcg  gag gag ctc      4869
Leu Ser  Ala Asn Ser Gly Ala  Arg Leu Gly Ile Ala  Glu Glu Leu
    1610                 1615                 1620

ttg cac  atc ttc aag gcg gcc  ttc gtt gac ccc gca  aag cct tcc      4914
Leu His  Ile Phe Lys Ala Ala  Phe Val Asp Pro Ala  Lys Pro Ser
    1625                 1630                 1635

atg ggt  att aag tat cta tac  ttg acc cct gaa act  tta tcc act      4959
Met Gly  Ile Lys Tyr Leu Tyr  Leu Thr Pro Glu Thr  Leu Ser Thr
    1640                 1645                 1650

ctt gcc  aag aag gga tcc agc  gtc acc act gag gag  atc gag gat      5004
Leu Ala  Lys Lys Gly Ser Ser  Val Thr Thr Glu Glu  Ile Glu Asp
    1655                 1660                 1665
gac ggc  gag cga cga cac aag  atc acc gcc atc atc  ggt ctt gca      5049
Asp Gly  Glu Arg Arg His Lys  Ile Thr Ala Ile Ile  Gly Leu Ala
    1670                 1675                 1680

gag ggt  ttg gga gtt gag tct  ctt cga gga tcc ggt  ctt att gct      5094
Glu Gly  Leu Gly Val Glu Ser  Leu Arg Gly Ser Gly  Leu Ile Ala
    1685                 1690                 1695

gga gcc  acc act cga gct tac  gag gag gga atc ttc  acc atc tct      5139
Gly Ala  Thr Thr Arg Ala Tyr  Glu Glu Gly Ile Phe  Thr Ile Ser
    1700                 1705                 1710
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ctc gtt act gcc cga tcg gtc ggt atc gga gct tac ttg gtt cga 5184
Leu Val Thr Ala Arg Ser Val Gly Ile Gly Ala Tyr Leu Val Arg
1715 1720 1725

ttg ggt cag cga gct att cag gtt gaa ggc aac cct atg atc ctt 5229
Leu Gly Gln Arg Ala Ile Gln Val Glu Gly Asn Pro Met Ile Leu
1730 1735 1740

act gga gct cag tct ctc aac aag gtg ctt gga cga gag gtt tac 5274
Thr Gly Ala Gln Ser Leu Asn Lys Val Leu Gly Arg Glu Val Tyr
1745 1750 1755

act tcc aac ctt cag ctt gga gga acc cag att atg gcc cga aac 5319
Thr Ser Asn Leu Gln Leu Gly Gly Thr Gln Ile Met Ala Arg Asn
1760 1765 1770

ggt acc acg cat ctc gtc gct gaa tct gat ctc gat ggt gct ctc 5364
Gly Thr Thr His Leu Val Ala Glu Ser Asp Leu Asp Gly Ala Leu
1775 1780 1785

aag gtc atc cag tgg ctc tcg tat gtg ccc gag cga aag ggc aag 5409
Lys Val Ile Gln Trp Leu Ser Tyr Val Pro Glu Arg Lys Gly Lys
1790 1795 1800

gcc att cct atc tgg cct tcc gag gac cct tgg gac cga act gtg 5454
Ala Ile Pro Ile Trp Pro Ser Glu Asp Pro Trp Asp Arg Thr Val
1805 1810 1815

acc tac gag cct ccc cga ggt cct tac gat cct cga tgg ttg ctt 5499
Thr Tyr Glu Pro Pro Arg Gly Pro Tyr Asp Pro Arg Trp Leu Leu
1820 1825 1830

gaa gga aag ccg gat gaa ggc ttg act ggt ctt ttc gac aag gga 5544
Glu Gly Lys Pro Asp Glu Gly Leu Thr Gly Leu Phe Asp Lys Gly
1835 1840 1845

tct ttc atg gag acc ctt gga gat tgg gcc aag act atc gtc acc 5589
Ser Phe Met Glu Thr Leu Gly Asp Trp Ala Lys Thr Ile Val Thr
1850 1855 1860

ggt cga gcc cga ctg gga ggc att cct atg ggt gtt att gct gtc 5634
Gly Arg Ala Arg Leu Gly Gly Ile Pro Met Gly Val Ile Ala Val
1865 1870 1875

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gaa acc  agg acg acc gag aag  atc atc gct gcc gat  cct gcc aac      5679
Glu Thr  Arg Thr Thr Glu Lys  Ile Ile Ala Ala Asp  Pro Ala Asn
    1880                 1885                 1890

cct gca  gct ttc gag caa aag  att atg gag gct ggt  cag gtt tgg      5724
Pro Ala  Ala Phe Glu Gln Lys  Ile Met Glu Ala Gly  Gln Val Trp
    1895                 1900                 1905

aac ccc  aac gct gct tac aag  acc gct caa tcc atc  ttt gat atc      5769
Asn Pro  Asn Ala Ala Tyr Lys  Thr Ala Gln Ser Ile  Phe Asp Ile
    1910                 1915                 1920

aac aag  gag ggt ctt cct ttg  atg atc ctt gcc aac  atc cga ggt      5814
Asn Lys  Glu Gly Leu Pro Leu  Met Ile Leu Ala Asn  Ile Arg Gly
    1925                 1930                 1935

ttc tct  gga gga cag ggt gat  atg ttt gac gct atc  ctc aag cag      5859
Phe Ser  Gly Gly Gln Gly Asp  Met Phe Asp Ala Ile  Leu Lys Gln
    1940                 1945                 1950

ggt tct  aag atc gtt gac ggt  ctc tcg aac ttc aag  cag cca gtg      5904
Gly Ser  Lys Ile Val Asp Gly  Leu Ser Asn Phe Lys  Gln Pro Val
    1955                 1960                 1965

ttc gtc  tat gtt gtc ccc aac  gga gag ctt cgt gga  gga gct tgg      5949
Phe Val  Tyr Val Val Pro Asn  Gly Glu Leu Arg Gly  Gly Ala Trp
    1970                 1975                 1980

gtc gtg  ttg gat cct act atc  aac ctt gcc aag atg  gag atg tac      5994
Val Val  Leu Asp Pro Thr Ile  Asn Leu Ala Lys Met  Glu Met Tyr
    1985                 1990                 1995
gct gat  gaa acc gct cga gga  gga att ctc gag ccg  gaa ggt atc      6039
Ala Asp  Glu Thr Ala Arg Gly  Gly Ile Leu Glu Pro  Glu Gly Ile
    2000                 2005                 2010

gtt gag  atc aag ttc cga cga  gac aag gtc atc gct  acc atg gag      6084
Val Glu  Ile Lys Phe Arg Arg  Asp Lys Val Ile Ala  Thr Met Glu
    2015                 2020                 2025

cga ttg  gac gag acc tat gcc  tct ctc aaa gct gcc  tcg aac gac      6129
Arg Leu  Asp Glu Thr Tyr Ala  Ser Leu Lys Ala Ala  Ser Asn Asp
    2030                 2035                 2040
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tca acc  aag tct gcg gag gag  cga gct aag agt gct  gag cta ctc      6174
Ser Thr  Lys Ser Ala Glu Glu  Arg Ala Lys Ser Ala  Glu Leu Leu
    2045                 2050                 2055

aag gca  aga gag act cta ctt  caa ccg acg tac ttg  cag att gca      6219
Lys Ala  Arg Glu Thr Leu Leu  Gln Pro Thr Tyr Leu  Gln Ile Ala
    2060                 2065                 2070

cac ctt  tac gct gat ctc cat  gat cgt gtc gga cga  atg gag gcc      6264
His Leu  Tyr Ala Asp Leu His  Asp Arg Val Gly Arg  Met Glu Ala
    2075                 2080                 2085

aag ggt  tgc gcg aag cga gct  gtc tgg gct gag gct  cga cga ttc      6309
Lys Gly  Cys Ala Lys Arg Ala  Val Trp Ala Glu Ala  Arg Arg Phe
    2090                 2095                 2100

ttc tac  tgg cga ctt cga cga  cgt ctc aac gat gag  cac atc ctg      6354
Phe Tyr  Trp Arg Leu Arg Arg  Arg Leu Asn Asp Glu  His Ile Leu
    2105                 2110                 2115

tct aag  ttc gct gct gcc aac  ccg gat ctt act ctc  gag gag cga      6399
Ser Lys  Phe Ala Ala Ala Asn  Pro Asp Leu Thr Leu  Glu Glu Arg
    2120                 2125                 2130

caa aac  att ctc gac tct gtc  gtc cag act gac ctc  act gat gac      6444
Gln Asn  Ile Leu Asp Ser Val  Val Gln Thr Asp Leu  Thr Asp Asp
    2135                 2140                 2145

cga gcc  acc gct gaa tgg att  gag cag tct gca gaa  gag att gct      6489
Arg Ala  Thr Ala Glu Trp Ile  Glu Gln Ser Ala Glu  Glu Ile Ala
    2150                 2155                 2160
gct gcc  gtt gcc gaa gtc cga  tcc acc tac gtg tcg  aat aag att      6534
Ala Ala  Val Ala Glu Val Arg  Ser Thr Tyr Val Ser  Asn Lys Ile
    2165                 2170                 2175

atc agc  ttc gcc gag acg gag  cga gct gga gcg ttg  cag ggc ttg      6579
Ile Ser  Phe Ala Glu Thr Glu  Arg Ala Gly Ala Leu  Gln Gly Leu
    2180                 2185                 2190

gtc gct  gtc ttg agc act ttg  aat gcg gaa gac aag  aag gcc ctt      6624
Val Ala  Val Leu Ser Thr Leu  Asn Ala Glu Asp Lys  Lys Ala Leu
    2195                 2200                 2205
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Val Ser Ser Leu Gly Leu
2210

<210> 3
<211> 2214
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<400> 3

Met Val Val Asp His Glu Ser Val Arg His Phe Ile Gly Gly Asn Ala
1 5 10 15

Leu Glu Asn Ala Pro Pro Ser Ser Val Thr Asp Phe Val Arg Ser Gln
20 25 30

Asp Gly His Thr Val Ile Thr Lys Val Leu Ile Ala Asn Asn Gly Ile
35 40 45

Ala Ala Val Lys Glu Ile Arg Ser Val Arg Lys Trp Ala Tyr Glu Thr
50 55 60

Phe Gly Asp Glu Arg Ala Ile Glu Phe Thr Val Met Ala Thr Pro Glu
65 70 75 80

Asp Leu Lys Val Asn Cys Asp Tyr Ile Arg Met Ala Asp Arg Val Val
85 90 95

Glu Val Pro Gly Gly Thr Asn Asn Asn Asn His Ser Asn Val Asp Leu
100 105 110
Ile Val Asp Ile Ala Glu Arg Phe Asn Ile His Ala Val Trp Ala Gly
115 120 125

Trp Gly His Ala Ser Glu Asn Pro Arg Leu Pro Glu Ser Leu Ala Ala
130 135 140

Ser Lys Asn Lys Ile Val Phe Ile Gly Pro Pro Gly Ser Ala Met Arg
145 150 155 160

Ser Leu Gly Asp Lys Ile Ser Ser Thr Ile Val Ala Gln Ser Ala Gln
165 170 175

Val Pro Cys Met Ala Trp Ser Gly Ser Gly Ile Thr Asp Thr Glu Leu
180 185 190

Ser Pro Gln Gly Phe Val Thr Val Pro Asp Gly Pro Tyr Gln Ala Ala
195 200 205

Cys Val Lys Thr Val Glu Asp Gly Leu Val Arg Ala Glu Lys Ile Gly
210 215 220

Leu Pro Val Met Ile Lys Ala Ser Glu Gly Gly Gly Gly Lys Gly Ile
225 230 235 240

Arg Met Val His Ser Met Asp Thr Phe Lys Asn Ser Tyr Asn Ser Val
245 250 255

Ala Ser Glu Val Pro Gly Ser Pro Ile Phe Ile Met Ala Leu Ala Gly
260 265 270

Ser Ala Arg His Leu Glu Val Gln Leu Leu Ala Asp Gln Tyr Gly Asn
275 280 285

Ala Ile Ser Leu Phe Gly Arg Asp Cys Ser Val Gln Arg Arg His Gln
290 295 300

Lys Ile Ile Glu Glu Ala Pro Val Thr Ile Ala Arg Pro Glu Arg Phe
305 310 315 320

Glu Glu Met Glu Lys Ala Ala Val Arg Leu Ala Lys Leu Val Gly Tyr
325 330 335

Val Ser Ala Gly Thr Val Glu Tyr Leu Tyr Ser His Ala Asp Asp Ser
340 345 350

Phe Phe Phe Leu Glu Leu Asn Pro Arg Leu Gln Val Glu His Pro Thr
355 360 365

Thr Glu Met Val Ser Gly Val Asn Leu Pro Ala Ala Gln Leu Gln Ile
370 375 380

Ala Met Gly Ile Pro Leu Ser Arg Ile Arg Asp Ile Arg Val Leu Tyr
385 390 395 400

Gly Leu Asp Pro His Thr Val Ser Glu Ile Asp Phe Asp Ser Ser Arg
405 410 415

Ala Glu Ser Val Gln Thr Gln Arg Lys Pro Arg Pro Lys Gly His Val
420 425 430

Ile Ala Cys Arg Ile Thr Ser Glu Asn Pro Asp Glu Gly Phe Lys Pro
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Ser Ala Gly Asp Ile Gln Glu Leu Asn Phe Arg Ser Asn Thr Asn Val
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Trp Gly Tyr Phe Ser Val Gly Ala Thr Gly Gly Ile His Ser Phe Ala
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Asp Ser Gln Phe Gly His Val Phe Ala Tyr Gly Ser Asp Arg Thr Thr
485 490 495

Ala Arg Lys Asn Met Val Ile Ala Leu Lys Glu Leu Ser Ile Arg Gly
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Asp Phe Arg Thr Thr Val Glu Tyr Leu Ile Thr Leu Leu Glu Thr Ser
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Asp Phe Glu Gln Asn Ala Ile Thr Thr Ala Trp Leu Asp Gly Leu Ile
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Thr Asn Lys Leu Thr Ser Glu Arg Pro Asp Pro Ser Leu Ala Val Ile
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Cys Gly Ala Ile Val Lys Ala His Val Ala Ser Glu Asn Cys Trp Ala
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Glu Tyr Arg Arg Val Leu Asp Lys Gly Gln Val Pro Ser Lys Asp Thr
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Leu Lys Thr Val Phe Thr Leu Asp Phe Ile Tyr Glu Gly Val Arg Tyr
595 600 605

Asn Phe Thr Ala Ala Arg Ala Ser Leu Asn Thr Tyr Arg Leu Tyr Leu
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Asn Gly Gly Lys Thr Val Val Ser Ile Arg Pro Leu Ala Asp Gly Gly
625 630 635 640

Met Leu Val Leu Leu Asp Gly Arg Ser His Thr Leu Tyr Trp Arg Glu
645 650 655

Glu Val Gly Thr Leu Arg Ile Gln Val Asp Ala Lys Thr Cys Leu Ile
660 665 670

Glu Gln Glu Asn Asp Pro Thr Gln Leu Arg Ser Pro Ser Pro Gly Lys
675 680 685

Ile Ile Arg Phe Leu Val Glu Ser Gly Asp His Ile Ser Ser Gly Asp
690 695 700

Ile Tyr Ala Glu Val Glu Val Met Lys Met Ile Leu Pro Leu Ile Ala
705 710 715 720

Gln Glu Ser Gly His Val Gln Phe Val Lys Gln Ala Gly Val Thr Val
725 730 735

Asp Pro Gly Ala Ile Ile Gly Ile Leu Ser Leu Asp Asp Pro Thr Arg
740 745 750

Val Lys Lys Ala Lys Pro Phe Glu Gly Leu Leu Pro Val Thr Gly Leu
755 760 765

Pro Asn Leu Pro Gly Asn Arg Pro His Gln Arg Leu Gln Phe Gln Leu
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Glu Ser Ile Tyr Ser Val Leu Asp Gly Tyr Glu Ser Asp Ser Thr Ala
785 790 795 800

Thr Ile Leu Arg Ser Phe Ser Glu Asn Leu Tyr Asp Pro Asp Leu Ala
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Phe Gly Glu Ala Leu Ser Ile Ile Ser Val Leu Ser Gly Arg Met Pro
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Ala Asp Leu Glu Glu Ser Ile Arg Glu Val Ile Ser Glu Ala Gln Ser
835 840 845

Lys Pro His Ala Glu Phe Pro Gly Ser Lys Ile Leu Lys Val Val Glu
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Arg Tyr Ile Asp Asn Leu Arg Pro Gln Glu Arg Ala Met Val Arg Thr
865 870 875 880

Gln Ile Glu Pro Ile Val Gly Ile Ala Glu Lys Asn Val Gly Gly Pro
885 890 895

Lys Gly Tyr Ala Ser Tyr Val Leu Ala Thr Ile Leu Gln Lys Phe Leu
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Ala Val Glu Ala Val Phe Ala Thr Gly Ser Glu Glu Ala Ile Val Leu
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Gln Leu Arg Asp Glu Asn Arg Glu Ser Leu Asn Asp Val Leu Gly Leu
930 935 940

Val Leu Ala His Ser Arg Leu Ser Ala Arg Ser Lys Leu Val Leu Ser
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Val Phe Asp Leu Ile Lys Ser Met Gln Leu Leu Asn Asn Thr Glu Gly
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Ser Phe Leu His Lys Thr Met Lys Ala Leu Ala Asp Met Pro Thr Lys
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Ala Pro Leu Ala Ser Lys Val Ser Leu Lys Ala Arg Glu Ile Leu Ile
995 1000 1005

Ser Cys Ser Leu Pro Ser Tyr Glu Glu Arg Leu Phe Gln Met Glu
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Lys Ile Leu Asn Ser Ser Val Thr Thr Ser Tyr Tyr Gly Glu Thr
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Gly Gly Gly His Arg Asn Pro Ser Val Asp Val Leu Thr Glu Ile
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Ser Asn Ser Arg Phe Thr Val Tyr Asp Val Leu Ser Ser Phe Phe
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Lys His Asp Asp Pro Trp Ile Val Leu Ala Ser Leu Thr Val Tyr
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Lys Leu Asn Gln Pro Ile Ala Glu Ser Ser Thr Pro Arg Val Asp
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Ser Asn Arg Asp Val Tyr Arg Val Gly Ser Leu Ser Asp Leu Thr
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Tyr Lys Ile Lys Gln Ser Gln Thr Glu Pro Leu Arg Ala Gly Val
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Met Thr Ser Phe Asn Asn Leu Lys Glu Val Gln Asp Gly Leu Leu
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Asn Val Leu Ser Phe Phe Pro Ala Tyr His His Gln Asp Phe Thr
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Gln Arg His Gly Gln Asp Ser Ala Met Pro Asn Val Leu Asn Ile
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Ala Ile Arg Ala Phe Glu Glu Lys Asp Asp Met Ser Asp Leu Asp
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Trp Ala Lys Ser Val Glu Ser Leu Val Met Gln Met Ser Ala Glu
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Ile Gln Lys Lys Gly Ile Arg Arg Val Thr Phe Leu Val Cys Arg
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Lys Gly Val Tyr Pro Ser Tyr Phe Thr Phe Arg Gln Glu Gly Ala
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Gln Gly Pro Trp Arg Glu Glu Glu Lys Ile Arg Asn Ile Glu Pro
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Val Thr Pro Ile Phe Val Asp Asn Arg Gln Ile His Ile Tyr Lys
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Glu Tyr Leu Ile Ser Glu Cys Asp Arg Leu Leu Thr Asp Ile Leu
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Asp Ala Leu Glu Val Val Gly Ala Glu Thr Arg Asn Ala Asp Cys
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Asn His Val Gly Ile Asn Phe Ile Tyr Asn Val Leu Val Asp Phe
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Asp Asp Val Gln Glu Ala Leu Ala Gly Phe Ile Glu Arg His Gly
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Lys Arg Leu Trp Arg Leu Arg Val Thr Ala Ser Glu Ile Arg Met
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Val Leu Glu Asp Asp Glu Gly Asn Val Thr Pro Ile Arg Cys Cys
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Ile Glu Asn Val Ser Gly Phe Val Val Lys Tyr His Ala Tyr Gln
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Glu Val Glu Thr Glu Lys Gly Thr Thr Ile Leu Lys Ser Ile Gly
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Asp Leu Gly Pro Leu His Leu Gln Pro Val Asn His Ala Tyr Gln
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Thr Lys Asn Ser Leu Gln Pro Arg Arg Tyr Gln Ala His Leu Val
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Gly Thr Thr Tyr Val Tyr Asp Tyr Pro Asp Leu Phe Val Gln Ser
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Phe Lys Ile Gly Ser Phe Gly Pro Lys Glu Asp Asp Tyr Phe Phe
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Lys Ala Thr Glu Ile Ala Lys Lys Leu Gly Leu Pro Arg Ile Tyr
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Leu His Ile Phe Lys Ala Ala Phe Val Asp Pro Ala Lys Pro Ser
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Met Gly Ile Lys Tyr Leu Tyr Leu Thr Pro Glu Thr Leu Ser Thr
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Leu Ala Lys Lys Gly Ser Ser Val Thr Thr Glu Glu Ile Glu Asp
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Asp Gly Glu Arg Arg His Lys Ile Thr Ala Ile Ile Gly Leu Ala
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Glu Gly Leu Gly Val Glu Ser Leu Arg Gly Ser Gly Leu Ile Ala
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Gly Ala Thr Thr Arg Ala Tyr Glu Glu Gly Ile Phe Thr Ile Ser
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Leu Val Thr Ala Arg Ser Val Gly Ile Gly Ala Tyr Leu Val Arg
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Leu Gly Gln Arg Ala Ile Gln Val Glu Gly Asn Pro Met Ile Leu
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Thr Gly Ala Gln Ser Leu Asn Lys Val Leu Gly Arg Glu Val Tyr
1745 1750 1755

Thr Ser Asn Leu Gln Leu Gly Gly Thr Gln Ile Met Ala Arg Asn
1760 1765 1770

Gly Thr Thr His Leu Val Ala Glu Ser Asp Leu Asp Gly Ala Leu
1775 1780 1785

Lys Val Ile Gln Trp Leu Ser Tyr Val Pro Glu Arg Lys Gly Lys
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Ala Ile Pro Ile Trp Pro Ser Glu Asp Pro Trp Asp Arg Thr Val
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Thr Tyr Glu Pro Pro Arg Gly Pro Tyr Asp Pro Arg Trp Leu Leu
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Glu Gly Lys Pro Asp Glu Gly Leu Thr Gly Leu Phe Asp Lys Gly
1835 1840 1845

Ser Phe Met Glu Thr Leu Gly Asp Trp Ala Lys Thr Ile Val Thr
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Gly Arg Ala Arg Leu Gly Gly Ile Pro Met Gly Val Ile Ala Val
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Glu Thr Arg Thr Thr Glu Lys Ile Ile Ala Ala Asp Pro Ala Asn
1880 1885 1890

Pro Ala Ala Phe Glu Gln Lys Ile Met Glu Ala Gly Gln Val Trp
1895 1900 1905

Asn Pro Asn Ala Ala Tyr Lys Thr Ala Gln Ser Ile Phe Asp Ile
1910 1915 1920

Asn Lys Glu Gly Leu Pro Leu Met Ile Leu Ala Asn Ile Arg Gly
1925 1930 1935

Phe Ser Gly Gly Gln Gly Asp Met Phe Asp Ala Ile Leu Lys Gln
1940 1945 1950

Gly Ser Lys Ile Val Asp Gly Leu Ser Asn Phe Lys Gln Pro Val
1955 1960 1965

Phe Val Tyr Val Val Pro Asn Gly Glu Leu Arg Gly Gly Ala Trp
1970 1975 1980

Val Val Leu Asp Pro Thr Ile Asn Leu Ala Lys Met Glu Met Tyr
1985 1990 1995

Ala Asp Glu Thr Ala Arg Gly Gly Ile Leu Glu Pro Glu Gly Ile
2000 2005 2010

Val Glu Ile Lys Phe Arg Arg Asp Lys Val Ile Ala Thr Met Glu
2015 2020 2025

Arg Leu Asp Glu Thr Tyr Ala Ser Leu Lys Ala Ala Ser Asn Asp
2030 2035 2040

Ser Thr Lys Ser Ala Glu Glu Arg Ala Lys Ser Ala Glu Leu Leu
2045 2050 2055

Lys Ala Arg Glu Thr Leu Leu Gln Pro Thr Tyr Leu Gln Ile Ala
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His Leu Tyr Ala Asp Leu His Asp Arg Val Gly Arg Met Glu Ala
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Lys Gly Cys Ala Lys Arg Ala Val Trp Ala Glu Ala Arg Arg Phe
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Phe Tyr Trp Arg Leu Arg Arg Arg Leu Asn Asp Glu His Ile Leu
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Ser Lys Phe Ala Ala Ala Asn Pro Asp Leu Thr Leu Glu Glu Arg
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Gln Asn Ile Leu Asp Ser Val Val Gln Thr Asp Leu Thr Asp Asp
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Arg Ala Thr Ala Glu Trp Ile Glu Gln Ser Ala Glu Glu Ile Ala
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Ala Ala Val Ala Glu Val Arg Ser Thr Tyr Val Ser Asn Lys Ile
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Ile Ser Phe Ala Glu Thr Glu Arg Ala Gly Ala Leu Gln Gly Leu
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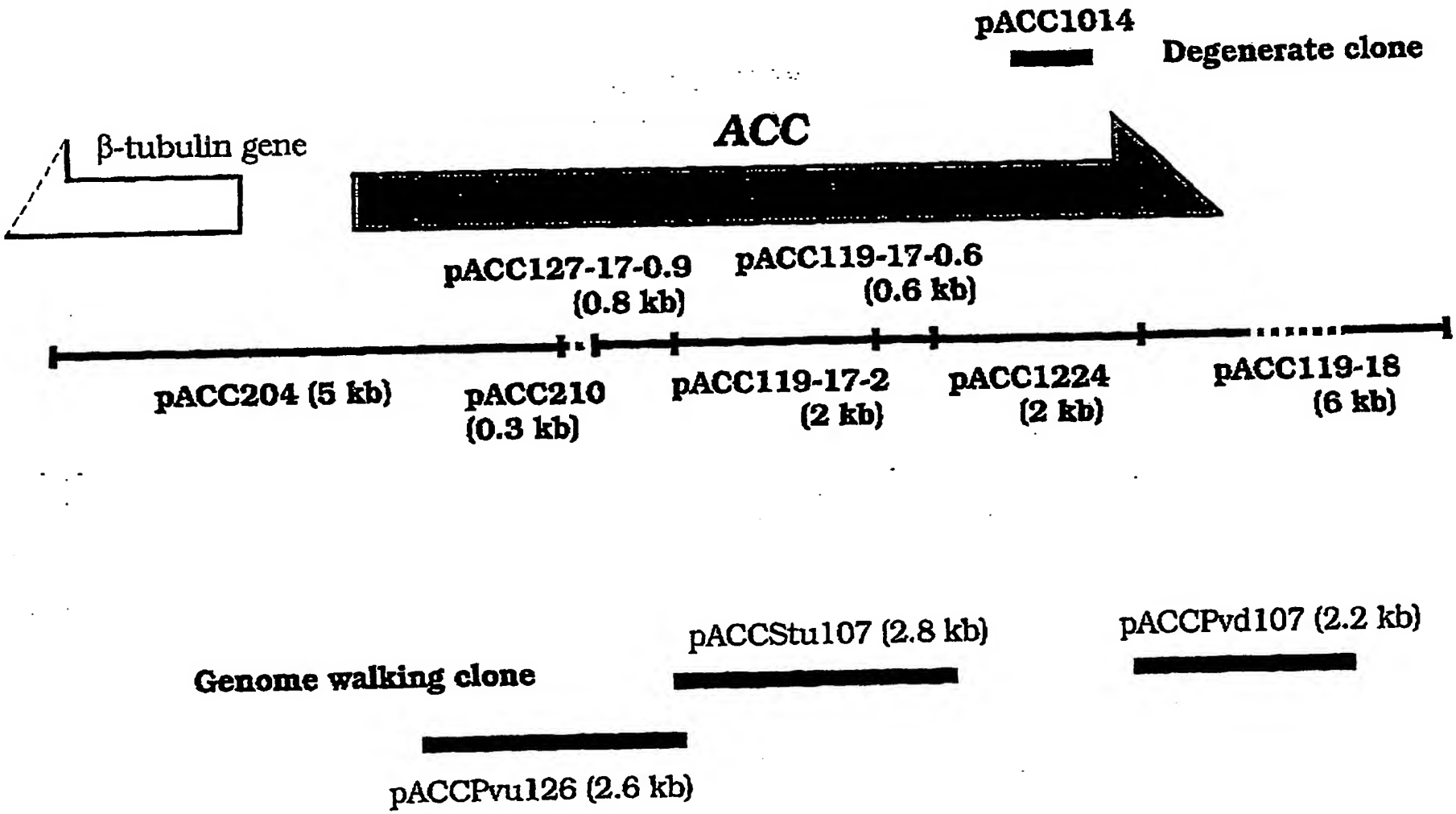

FIG.2 Cloning of *ACC* gene region from *P. rhodozyma*